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TECHNICAL MANUAL

This manual contains untested EOD procedures.

EXPLOSIVE ORDNANCE DISPOSAL PROCEDURES

PROTECTION OF PERSONNEL AND PROPERTY (RELEASE-4)

This complete revision supersedes Revision 4 dated 06 October 2001

Published under authority of the Secretaries of the Army, Navy, and Air Force.
(Prepared by the Naval Explosive Ordnance Disposal Technology Division,
2008 Stump Neck Road, Indian Head, MD 20640-5070)

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SAFETY SUMMARY

WARNINGS

Be aware that non-case fragments (rogue fragments) such as nose plugs, suspension lugs, strongbacks, and baseplates, may be projected to distances greater than 10,000 feet (3,048 meters). These distances are normally greater than the primary fragment dispersal range.

Increase the fragmentation distance ranges by 33 percent when intentionally disposing of ammunition and explosives placed in stacks or piles. Detonation of munitions in stacks can project fragments to greater distances than detonation of multiple items arranged in a side-by-side orientation.

Increase the fragmentation distance ranges by 33 percent when explosive ordnance items are stacked or haphazardly piled up as a result of an accident/incident. Detonation of munitions in stacks can project fragment ranges to greater distances than for detonation of multiple items arranged in a side-by-side orientation.

Ensure that all personnel located at the Hazardous Fragmentation Distance Range are afforded adequate frontal and overhead protection against explosion effects. At this distance, personnel remaining in the open may incur injury or death from being struck by a hazardous fragment(s). Risks associated with explosion effects increase for distances closer than the hazardous fragmentation distance range.

Ensure personnel are advised to remain away from exterior windows when located at the Hazardous Fragmentation Distance Range. Flying and/or falling glass hazards are expected at this distance range.

Use caution when marking a buried UXO when the type-by-function is in question and/or its depth is questionable. Driving a stake or similar holding device into the surface at the point over the estimated location of a buried UXO could initiate sensitive fuzing or impact the UXO itself causing it to detonate.

CHAPTER 1. INTRODUCTION.

1-1. PURPOSE. This manual provides EOD personnel with methodologies to manage risks associated with the explosion effects of ammunition and explosives (AE) by providing minimal protection criteria to minimize serious injury, loss of life, and damage to property. It is applicable to associated DOD personnel and property, and to unrelated personnel and property (public) exposed to the potential damaging effects of an incident or accident involving AE during the development, manufacturing, testing, transportation, handling, storage, maintenance, demilitarization, and disposal. This manual includes minimal safety standards established by the Department of Defense Explosive Safety Board (DDESB) 6055.9-STD; greater protection should be provided whenever feasible. For the purposes of this manual, AE includes all categories of explosive ordnance, unexploded ordnance (UXO), and improvised explosive devices (IEDs) to include large improvised explosive devices (LIED) and large vehicle borne improvised explosive devices (LVBIEDs).

1-2. SCOPE.

a. Chapter 2 of this manual describes basic explosion phenomena relationship to personnel and material. Primary subject matter includes blast overpressure, and fragmentation descriptions to include buried explosion effects in relation to debris throw and flyrock hazards.

b. Chapter 3 of this manual establishes procedures and methods to determine minimal quantity distance ranges (QDRs) (withdrawal distances) for essential and nonessential personnel/public. Subject areas include QDR description, determinations, procedures and methods for the protection against explosion effects. Methods to determine a potential flyrock event and QDRs are also provided. Mitigation and protective measures to reduce explosion effects are also provided.

c. The final portion of this manual provides additional resource information, terminology and definitions, and incident examples.

1-3. SPECIFIC SUMMARY OF CHANGES.

NOTE

This manual has undergone a major revision to adopt new methodologies to determine minimal protective measures for the protection against explosion effects. EOD personnel are strongly encouraged to review the entire manual and conduct training exercises in order to become familiar with its contents. Training and exercises will eliminate confusion for a real-time scenario. The following is a brief summary of material changes:

a. New warnings have been added to the Safety Summary and include subject matter as follows:

(1) Rogue fragments.

(2) Increase primary fragment withdrawal distances for AE configured in stacks or piles.

(3) Explosion related risks associated with the Hazardous Fragmentation Distance Range (HFDR).

b. Chapter 2 has been expanded to include basic explosion phenomena and its effects to personnel and material. The following is a list of new subjects added:

(1) Blast load categories.

(2) Effects of reflected blast waves.

(3) Overpressure effects to personnel and material or structures.

c. Chapter 3 is an entirely new chapter that includes methods to determine protective measures for personnel and material or structures. New information includes:

(1) Performance of a risk and decision analysis for AE involved in an incident or accident.

(2) Methods to determine the amount of explosives involved, known as the Net Explosive Weight Quantity Distance or NEWQD.

(3) Guidelines to determine the type and quantity of explosive material by Hazard Division class.

(4) Methods, either by tables provided or equation, to determine the Blast Overpressure Distance Range (BODR).

(5) New fragmentation withdrawal distance known as Hazardous Fragmentation Distance Range (HFDR) and how to determine it by the diameter of an elongated cylindrical ordnance shape or by the net explosive weight of the subject item of concern. Distance may be derived by tables provided or by equation work.

(6) New fragmentation withdrawal distance known as the Maximum Fragmentation Distance Range (MFDR) and how to determine it by the diameter of an elongated cylindrical ordnance shape or by the net explosive weight of the subject item of concern. Distances may be derived by tables provided or by equation work.

(7) New criteria to determine which circumstances, and when and to whom the new blast and/or fragmentation distance ranges apply.

(8) New withdrawal distances derived from table provided, for debris throw for a buried AE item.

(9) New information regarding how to determine a potential flyrock event, and withdrawal distance for a potential flyrock event for AE located within caves or tunnels.

(10) Revised as well as new information regarding methods to mitigate and/or protect against explosion effects.

d. Addition of three appendices that include:

(1) Guidelines to determine the explosive content of an unknown item for the purposes of establishing withdrawal distances.

(2) Terminology and definitions of new specific terms used in the manual.

(3) New examples designed to provide a methodical approach of how to derive blast overpressure and fragmentation distance ranges.

CHAPTER 2. DESCRIPTION.

2-1. BLAST WAVE PHENOMENA.

a. Blast Wave Effects. When a detonation occurs involving AE, such as those defined as mass detonating and mass detonating fragment-producing, a violent release of energy creates a sudden and intense pressure disturbance known as the shock front or blast wave. The blast wave (a thin layer of compressed air about 0.00001-inch thick) is characterized by an almost instantaneous rise from ambient pressure to a peak incident pressure. This pressure increase or shock front, travels radially outward from the detonation point, with a diminishing velocity that is always in excess of the speed of sound in that medium. Gas molecules or blast wind, immediately behind the front, moves at lower velocities, but still at super-hurricane force velocity. This velocity, which is called the particle velocity, is associated with the dynamic pressure or the pressure formed by the winds produced by the shock wave. As the blast wave expands into increasingly larger volumes of medium, the incident pressure decreases and the duration of the pressure-pulse increases. As the blast wave decays, it degenerates into an acoustic wave. At these lower values, the airflow then reverses direction. Eventually, the pressure, density, and temperature return to normal.

b. Blast wave time record. At any point away from the detonation, the pressure disturbance has the shape shown in figure 2-1. The shock front arrives at a given location arrival time and, after the rise to the peak incident pressure value, the incident pressure decays to the ambient pressure value, thus the positive phase duration. Following is the negative phase duration which is usually much longer that the positive phase. The negative phase is characterized by a negative pressure as well as particle flow reversal.

c. Overpressure effects. Representative physical effects of a typical blast wave are shown in figure 2-2. At Time A, the atmosphere is undisturbed. Time B is immediately after the shock wave and blast winds have impacted an exposure. The blast wave effects then decrease until the pressure reaches atmospheric pressure; afterward is a slight negative phase at Time C along with a reverse blast wind. Time

D is after the blast wave subsides.

d. Duration. Time duration of the blast wave is one aspect of its ability to cause damage since the damage inflicted depends in part on how long the damaging forces are applied. Since the positive phase of the blast wave is the more damaging one, the duration of this phase can be measured more precisely. The positive pressure duration can be taken as an index of the time duration for the entire blast wave system even though ordinarily the negative phase seems to last about twice as long as the positive phase.

e. Impulse. Impulse is defined as the product of force application and the duration of the application. Impulse is an important aspect of damage-causing ability of the blast overpressure, and may become a controlling item for some situations. The significant portion of blast impulse is that associated with the positive phase.

2-2. BLAST LOAD CATEGORIES. Blast loads on structures can be categorized as unconfined or confined and can be subdivided based on the blast loading produced within the donor structure or acting on acceptor structures.

a. Unconfined Explosions. Unconfined explosions are subcategorized into the following:

(1) Free-Air Burst Explosion. A free-air burst explosion figure 2-3 occurs in free-air adjacent to and above a structure so that no amplification of the incident wave occurs between the explosive site and the structure. Pressure load is not reflected as the initial output incident blast wave propagates away from the center of the detonation. The blast wave impinges on the structure without intermediate amplification. As the incident wave impinges the structure, the incident wave is reflected. As the incident wave impinges on the ground surface, then the point of initial contact is said to sustain the maximum normal reflected pressure and impulse.

(2) Air Burst Explosion. An air burst explosion figure 2-4 is produced by a detonation that occurs above the ground surface so that the incident wave impinges (reflects) off the ground surface prior to arrival at the structure. As the blast wave continues to propagate outward along the ground surface, a front known as the Mach front is formed by the interaction of the initial incident wave and the reflected wave. The height of the Mach front increases as the wave propagates away from the detonation site. The increase in height is referred to as the path of the triple point and is formed by the intersection of the initial, reflected, and the Mach front. When the height of the triple point exceeds the height of the structure, a uniform pressure is applied. If the height of the triple point does not extend above the height of a multistory structure, the magnitude of the applied loads will vary. Since the magnitude of pressures above the triple point are smaller than that of the Mach front, the effect to the structure will likely have more damage and lower levels.

(3) Surface Burst Explosion. A surface burst explosion figure 2-5 is a detonation at or very near the ground surface. The incident wave is reflected and reinforced by the ground surface to produce a reflected wave. Unlike an air burst detonation, the reflective wave merges with the incident wave at the point of detonation forming a single wave similar in nature to the Mach wave of an air burst detonation, but

essentially hemispherical in shape. It should be noted that peak overpressures and impulse by a detonation at or very near the ground surface are generally much greater and cause more damage. As the reflected blast wave impinges a structure wall face-on, the wave movement is brought to zero. The wave is reflected again, thus pressure is again amplified. This amplification of the overpressure wave increases the pound-per-square-inch (psi) value by two or more over the original incident overpressure.

b. Confined Explosions. When an explosion occurs within a structure, peak pressures associated with the initial shock wave will be extremely high and will be amplified by additional reflections within the structure. In addition, depending upon the degree of confinement, the effects of the high temperatures and accumulation of gaseous products produced by the chemical process involved in the explosion will exert additional pressures and increase the load duration within the structure. The combined effects will eventually destroy the structure unless the structure is designed to sustain such effects. Openings such as windows and doors will fail, allowing the pressure to spill over the surrounding ground reducing the magnitude and duration of the internal pressures.

2-3. REFLECTED BLAST WAVE PHENOMENA.

a. When the shock wave impinges a rigid surface at an angle to the direction of the wave propagation, a reflected pressure wave is instantly developed on the impinged surface. The reflected pressure is a function of the incident pressure wave and the angle formed between the rigid surface and the plane of the shock front. Depending upon the ground surface composition (concrete versus soil), some energy may be dissipated into the ground (ground cratering and ground shock) so only a partial reflection and overpressure strengthening occurs. In addition, the reflected incident wave may also be affected by irregular ground/terrain surfaces, atmospheric conditions, and structures/objects to which it impinges as it travels outward. There are three typical blast wave reflections.

(1) Normal reflection. Normal reflection figure 2-6 occurs when the shock wave impinges face-on onto an unyielding surface.

(2) Oblique reflection. Oblique reflection figure 2-7 occurs when the shock wave impinges with an angle between the plane of the shock front and the plane of the reflecting surface. Oblique reflections from smaller angles are generally less intense, but as the impinging incident wave angle increases, reflected pressures will at least be double the incident pressure.

(3) Mach stem reflection. Mach stem formation figure 2-4 occurs when the detonation occurs above the ground surface such as in an air burst explosion. The shock wave impinges on the ground surface and propagates outward along the ground surface. At a certain distance along the ground, the reflected wave combines with the incident wave to form a third wave that has a vertical front at ground level. This third wave is called the Mach wave or stem. The point where the three waves intersect is the triple point. At the triple point where the incident wave is reinforced by the reflected blast wave, both peak pressure and impulse pressure are at the maximum; each is considerably higher in value than the original blast wave at the same distance from the point of detonation.

b. Focusing Conditions. Blast waves are also enhanced or focused by confinement. For example, a blast wave traveling through a tunnel, corridor, trench or even a city street, decreases in intensity slower than if in the open. If a bomb detonates in a building, there is considerable blast wave reflection even if the walls are demolished. Underground and underwater blast effects of a detonation are more comparable with open-air effects than those under confinement. Weak blast waves resembling sound waves are influenced to some degree by factors that influence ordinary sound waves. One example is the effect of an atmospheric inversion; atmospheric temperature and associated speeds of sound are higher at moderate elevations than they are near the surface. This can deflect a weak blast wave and redirect it downward towards the surface, just as it can redirect a sound wave back toward the surface. This effect could enhance the blast wave several times.

2-4. BLAST RELATED EFFECTS TO PERSONNEL, MATERIAL, AND STRUCTURES.

a. Scaled Distance. Scaled distance, otherwise known as a K-factor, is a multiplication factor generally used to determine distance from the explosion site to a particular exposure of concern. Overpressure effects scale or vary as a function of the separation distance between the detonation site and an exposure. For example, the overpressure value will vary as it travels away from the initial point of the explosion. A withdrawal distance derived using a specific K-factor will equate to a defined effect, such as a pound-per-square inch value for overpressure value at that distance regardless of the amount of explosives involved. In English units the K-factor is shown as K for distance in feet, followed by a number value. In Metric units, K-factor followed by a number value is shown as K(m) for distance in meters. If a separation distance from a detonation site is known, and the amount of explosives is also known, a K-factor at that distance can be calculated by dividing the distance by the cube root of the amount of explosive involved. Table 2-1 lists K-factors and corresponding overpressure values.

b. Personnel Effects.

(1) Human Blast Tolerance. It has been shown that human blast tolerance varies with both the magnitude of the shock pressure and the shock duration, i.e., the pressure tolerance for short duration peak blast pressure (3-5 milliseconds) is significantly higher than for long-duration impulse blast pressure (above 50 milliseconds). Thresholds for lung damage and lethality are a function of both pressure and impulse. At the same distance, overpressures will be the same but impulses will vary with the charge weight.

NOTE

Lung damage and lethality are a function of both incident overpressure and positive phase impulse. At a particular distance (and corresponding K-factor), incident overpressures will be the same, but positive phase impulses will vary with the charge weight. Thus, to determine the percent level of lung damage or lethality, the charge weight must first be estimated or known, and then a calculation must be performed on a case-by-case basis.

Damage is most marked in the air-containing tissue of the body: the eardrums, the sinuses and the lungs; nearby soft tissue is especially sensitive to blast damage. Lung damage resulting in "air" bubbles reaching general circulation, including vessels of the heart and brain, is the most dangerous and is usually fatal within a few minutes. Suffocation from lung hemorrhage and edema accompanied by heart failure can occur early. Bruising of the heart, liver, spleen, and abdominal organs, along with areas of hemorrhage and rupturing of hollow organs can occur. The orientation of a person standing, sitting, prone, face-on or side-on to the blast pressure as well as the shape of the pressure front (fast or long duration rise) are significant factors in the amount of injury sustained. All personnel protection must limit blast overpressure to 2.3 pounds-per-square inch. This would equate to a scaled distance K-factor of 24. At this overpressure, injury or lethality in relation to the lungs or other major body organs, need not be considered. Whenever possible, it is recommended that all nonessential personnel not be exposed to blast overpressure in excess of 0.066 pounds-per-square inch (psi) (0.45 kilopascal (kPa), equivalent to a scaled distance of K328 (K(m) 130.1). This is also the preferred exposure level for essential personnel when exposed in the open.

(2) Table 2-2 lists effects to unprotected ears due to blast overpressure. As noted in the Table 2-1, sound overpressures are much greater to unprotected ears.

c. Material and Structural Effects.

(1) The damage to a structure is a function of the magnitude of the detonation, the location of the potential explosive site relative to the structure, the shape of the structure, and the structure construction. An additional consideration is the structure orientation with respect to the detonation and the ground surface (above, flush with, or below ground).

(2) Conventional structures are generally designed to withstand roof-snow loads of 50 pounds per-square-foot, or winds loads up to 90 miles-per-hour or both. A 90 mile-per-hour wind load equates to about 0.14 pounds-per-square-inch (PSI). This would equate to a scaled distance K-factor of about 197. Pressure related damaging effects to conventional structures at this scaled distance would likely be minimal. Table 2-3(Sheet 1), (Sheet 2) lists expected overpressure effects to select material and structures.

(3) When a shock front strikes a wall of a structure, the blast wave pressure is amplified. Windows and doors will fail almost immediately (approximately 1 millisecond) after the onset of the shock front unless they are designed to resist the applied overpressure loads. This sudden release of high pressure will cause a shock front to form inside of each opening. Each individual front will expand and tend to combine into a single front that will further expand throughout the structure's interior. This interior shock is initially weaker than the incident pressure at the building's exterior. However, the interior pressure will tend to get stronger due to reflections off interior building walls and components. As the exterior blast wave continues forward movement, it diffracts around and engulfs the structure with the resulting pressure on the front face of the building dropping rapidly to the sum of the initial ground reflected incident wave overpressure. Blast loading pressures on the side and rear walls of the structure are about equal to the initial incident overpressure wave.

(4) Ground Shock and Cratering. In an air burst explosion, there may be downward propagation of ground shock, but cratering may be little or none. Ground shock from the surface or slightly below the surface normally generates a crater with the strongest ground shock. If the explosion is deep enough, the formation of a camouflet is likely.

2-5. FRAGMENT AND DEBRIS RELATED HAZARDS.

a. Primary Fragments. Primary fragments are from material that is in intimate contact with explosive material. They are created from the shattering of explosive-filled containers such as explosive ordnance, improvised explosive devices, and other containers used in manufacturing or storing and shipping of explosive materials. Primary fragments usually are small, initially traveling at thousands of feet-per-second and may be lethal at long distances from the initial potential explosive site.

b. Secondary Fragments. Secondary fragments are fragments produced by the impact of primary fragments or air blast into the surrounding environment. These fragments are generally larger in size than primary fragments and initially travel at hundreds of feet-per-second. Secondary fragments are not generally dispersed to the maximum ranges as are primary fragments.

c. Firebrand. Firebrand is a projected hot fragment, burning energetic material, or burning debris whose thermal energy is transferred to the surroundings.

d. Glazing (Glass) Fragment Hazards. One of the most far-reaching fragment hazards to personnel located inside buildings is from high-velocity window glass fragments. Overpressure required to shatter a window in a building is a function of the windowpane area and thickness, type of glass and mounting used, orientation of the window with respect to the blast wave, flaws in the glass, and stresses introduced when the glass was mounted into the frame. Table 2-4(Sheet 1), (Sheet 2) lists the probability of flying glass hazard effects for select annealed windows. Other than a no break incident, an increase in the seriousness of injuries to personnel is expected when they are positioned directly in-line to the effected window.

(1) Nature of Window Breakage. When a glass pane is dislodged from its mounting by a blast wave, almost the entire exposed portion of the pane shatters into numerous fragments. The windowpane breaks and forms a cloud that expands in all directions as it translates. The leading half of the cloud may be hemispherical in shape with a significant number of larger fragments appearing to have their flat surface tangent to the hemisphere. Fragments in the trailing half of the cloud may be in random orientation before translating 7 feet. For a given overpressure, a larger windowpane will produce larger fragments that tumble less than fragments from a smaller window.

(2) Annealed and Tempered Glass. Although many types of glass are produced, annealed glass and tempered glass are the most common. Tempered glass is produced by heating, then rapidly cooled. As a result, tempered glass is about four to five times stronger than annealed glass. Tempered glass (which will produce small fragments) will have relatively smooth edges when broken. Annealed glass, also called plate or plain glass, is by far the most common material used for window glass. During the manufacturing process, annealed glass is cooled slowly. Upon failure, annealed glass

fractures into razor-sharp, dagger-shaped fragments.

(3) Overpressure to Shatter Windows. Test results from large explosions have shown that a face-on incident overpressure for a 50 percent probability of failure for small to large surface area windowpanes is between 0.087 to .87 psi incident overpressure respectively. Face-on overpressure effects are essentially the same as side-on orientations. Fragment sizes tend to decrease with increasing overpressure.

(4) Density of Glass Fragments. Fragment spatial density tends to be uniform equal to the area of the window and decrease beyond this area. As the angle increases to about 20 degrees to the centerline axis of a window, the density of glass fragments is approximately one-tenth of the density measured directly behind the window.

(5) Biological Effects Related to Flying Glass. Injury types normally associated with flying glass are skin lacerations (penetration to approximately 3 millimeters or less), and penetration or puncture wounds (beyond 3 millimeters, but not penetrating through the abdomen and thorax). Body-wall injuries include the penetration or puncture of the thorax (18 millimeters for penetration between the ribs), and abdomen (penetration of 12 millimeters) with major organ injury possible. Skull fracture related injuries are related to the frontal (sinus area) of the skull. Expected biological effects to personnel exposed to flying glass are shown in table 2-4(Sheet 1), (Sheet 2) under the flying glass hazard categories. Injuries increase with an increase in overpressure and fragment velocity. The thickness of a fragment as well as its angle of impact is also the type of injury to be expected. At a given overpressure, a larger fragment, for example a 100-gram fragment, can cause a more serious injury than a 1-gram fragment. This is also true for translation distance ranges; heavier fragments will translate further than lighter fragments. Larger fragments also tend to translate in a manner that will result in a point-on impact rather than a random orientation impact that translates for lighter fragments. It should be noted that wearing light clothing, personnel could reduce the chances of injury from flying glass. Typical window draperies and blinds can also reduce fragment velocities and translation distances.

(6) Falling Glass Hazard. Falling glass hazards are simply glass fragments falling from some distance above, to the ground below. Falling glass can cause serious injury or death depending upon the mass of the glass fragment, its impact orientation, and the distance to target.The effects of a falling glass hazards may be delayed long after the initial explosion. Windy conditions, secondary explosions, or personnel movement about the post detonation site, may cause loose glass fragments to fall. Large shards of glass have been known to fall and penetrate through the roofs and into the interior seats of standard automobiles that were located on the street below the effected structure. This hazard could present itself at greater scaled distances calculated for essential personnel and could extend into nonessential personnel evacuation distance ranges.

e. Buried Ordnance Debris. As a buried munition explodes, primary fragments initially travel ahead of the overpressure blast wave through undisturbed soil before escaping into the air. Depending upon soil composition and the depth of the AE, primary fragment velocity is reduced and may stop movement prior to exiting the ground surface. However if the explosion is relatively close to the surface, a crater is formed. Large chunks of soil debris (secondary fragments) may be thrown from the center causing an earth debris ejection hazard. If the ordnance is deep enough, a camouflet is likely to be formed.

f. Fragment Dispersal from AE in Stacks or Piles. Fragmentation characteristics of multiple items that are oriented in stacks or piles are different than that for single item detonation. Large fragments tend to be more numerous and velocities of the leading fragments have been observed to be twice the value than for single item detonations. Generally, items on the side and top of a stacked configuration contribute to the greater size of fragments and further distance ranges.

g. Flyrock Hazards. When operations involve the demolition of AE cache located in caves, caverns, or tunnels, a serious earth debris event known as flyrock is possible. A flyrock event occurs when debris, primarily rocks and large chunks of soil, are propelled from a demolition site by the force of the explosion. High velocities and great throw ranges of flyrock may be caused by particle acceleration resulting from escaping gases of the explosion and from spalling.

(1) Gas particle acceleration effects. Gas acceleration is considered to be most dominant. When a rock mass contains weak zones, explosive gases will tend to escape along these paths of least resistance and concentrated in particular directions. Massive rock will tend to remain in large blocks that are loosened, while highly fractured or loose rock will be thrown out at high velocities by the escaping gas.

(2) Spalling effects. Flyrock from spalling is usually the result of an explosive detonation near the outside surface or interior wall between two or more chambers within a cave or tunnel. Velocities of spall-accelerated flyrock can be greater than that of gas-accelerated flyrock. Spall-accelerated anomalous flyrock can be thrown to very great distances. These distances are usually much further than the fragmentation distances for AE involved. Where a cave or tunnel has more than one chamber used for storage of AE, a detonation in one chamber could cause high-velocity spall flyrock to impact AE in another chamber causing it to detonate.

CHAPTER 3. PROCEDURES.

3-1. GENERAL. When AE is involved in an accident, incident, or a routine disposal operation, protective measures for personnel and material assets must be determined and implemented whenever possible against explosion effects. Explosion effects include blast overpressure, primary and secondary fragmentation or debris from buried ordnance explosion, earth shock, and heat flux from an explosion at the potential explosive site (PES). In order to implement protective measures, an incident risk and decision analysis should be conducted.

a. Incident Risk Analysis. In order to make decisions upon actions that will determine the size and scope of protective measures required for a given incident, a risk analysis should be performed. Information obtained from a thorough risk analysis will be required to determine quantity distance ranges (QDRs) for essential and nonessential personnel. The size and scope of the ES as well as the amount of risk acceptable to the identified exposures within the ES can then be established. The following are some risk analysis size-up factors to consider.

(1) Identifying the type, amount, and condition of the AE involved.

(2) Determining the nature of the accident/incident, or specific type of operation, i.e., do the circumstances involve an intentional detonation or is there an unacceptable risk that could cause an unintentional/accidental detonation.

(3) Determining what personnel are essential and those who are not for mission accomplishment, (accomplished by an on-site authority).

(4) Determining the availability as well as the integrity of protection available/required for within the ES.

(5) Identifying the protective requirements such as structures/facilities or barriers that offer protection against explosion effects for both essential and nonessential personnel.

(6) Determining protective requirements for critical material or structure exposures.

(7) Identifying any specific exposures that could result in an additional catastrophic event if exposed to explosion effects.

(8) Identifying any unacceptable procedures or operations that may result in an unintentional detonation.

b. Incident Decision Analysis. Once a risk analysis has been accomplished, decisions on actions can then be implemented. Actions normally will be based upon exposures, potential losses, and control/protective measures to protect personnel/public and material assets identified during initial risk analysis. The following are some incident response action requirements.

(1) Establishment of an ES from the PES or an adjustment to a previously established exclusionary area; plot QDRs to determine the ES, as well as distances from specific exposures within the ES as required.

(2) Evacuation of essential and nonessential personnel to applicable blast/fragmentation distance quantity distance ranges, or to structures/facilities that will provide a defined level of protection against explosion effects.

(3) Implementation of mitigation techniques to limit explosion effects within the ES.

(4) Identification and implementation of control measures that reduce or eliminate the unintentional/accidental initiation of the AE of concern.

(5) Identification and application of specialized EOD tools and/or techniques that reduce or eliminate the chance of an unintentional/accidental detonation for the incident at hand.

c. Net Explosive Weight Quantity Distance (NEWQD). The NEWQD expressed in English or Metric units, is the high explosive weight (including the TNT equivalency if known) of AE involved. Once determined, it is used to determine the blast and fragmentation quantity distance ranges. The NEWQD is equal to the total net explosive weight (NEW) for single, multiple like, or multiple mixed AE. If the TNT equivalent is not known, the NEWQD is the sum of all the NEW involved. Whenever the TNT equivalency is not known or is determined to be less than 1, minimal TNT equivalency of 1 shall be used. Table 3-1(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4) lists the TNT equivalency as well as the density for select explosives. Refer to table 3-2(Sheet 1), (Sheet 2) for cube roots values based on the higher amount of the explosive weight range given.

d. Guidelines for Determining the Type and Quantity of Explosives. To determine the NEWQD, it is important whenever possible to determine the composition and amount of explosive material involved. In addition, knowing the assigned hazard division (HD) for the AE involved will aid in determining withdrawal distances. Refer to appendix B for definitions of explosive classification divisions and compatibility groups.

(1) When in doubt as to what hazard division applies, consider the AE of concern as HD 1.1.

(2) For HD 1.1, HD 1.2, or HD 1.5, the NEWQD is the sum of the net explosive weight and the net propellant (solid or liquid) weight.

(3) For HD 1.3, HD 1.4, or HD 1.6, the NEWQD is the sum of the net explosive weight, net propellant weight, and the total weight of pyrotechnics.

(4) Include disposal explosives into the NEWQD when applicable.

e. Guidelines for Determining the NEWQD for Mixed AE.

(1) When in doubt as to what hazard class applies for mixed AE, consider all items of concern as HD 1.1.

(2) For HD 1.1 or HD 1.5 AE mixed with any other HD, treat the mixture as HD 1.1. Use not less than the TNT equivalent of the greater amount of high explosive to determine the NEWQD.

(3) For HD 1.3, HD 1.4, or HD 1.6 AE with HD 1.1 demolition explosives, treat the mixture as HD 1.1. Use not less than the TNT equivalent of the greater amount of high explosive to determine the NEWQD.

(4) For HD 1.3, HD 1.4, or HD 1.6, treat the total mixture as HD 1.3.

f. NEWQD Exclusions. Munition fillers that do not contribute to explosive effects, e.g., smokes, dyes, irritants, toxic chemical agents, white phosphorus (WP), and plasticizied white phosphorus (PWP), are excluded when determining NEWQD. If for example the munition of concern has a burster, use the net explosive weight of the burster to determine the NEWQD.

g. Quantity Distance Range Calculations and Usage. Quantity distance range (QDR) is the quantity of explosive material and the distance separation relationship that provides defined levels of protection. The relationships are based on levels of risk considered acceptable for specific exposures. The QDR for the blast overpressure distance range (BODR) and determining critical cover thickness (CCT) for flyrock concerns is also referred to as a scaled distance. The QDRs for fragmentation effects are referred to as the hazardous fragmentation distance range (HFDR) and the maximum fragmentation distance range (MFDR). They are based on the primary and secondary fragments from the PES to the population or traffic density of the ES. Computing the QDR for an AE of concern will establish and/or adjust the ES, define withdrawal distances for essential and nonessential personnel, and aid in predicting the potential effects to structures and material within the ES.

h. Calculating the BODR. In English units, the formula is expressed as $D=KW^{1/3}$; where D is the distance in feet, K is the constant multiplying factor for the effect desired or assumed risk, and $W^{1/3}$ is the cube root of the NEWQD in pounds. When metric units are used, the formula $D(m)=K(m)Q^{1/3}$; where D(m) is the distance in meters, K(m) is the constant multiplying factor in metric units, and $Q^{1/3}$ is cube root of the NEWQD in kilograms. The BODR is used in conjunction with the HFDR and the MFDR to determine the greater QDR. BODRs are listed in tables 3-3(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4) and Table 3-4(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4). Table 3-3(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4) lists the BODRs for unknown items up to 18 inches in diameter, and are based on the relationship between an estimated maximum explosive filler content for the listed diameter ranges.

NOTES

For simplicity from hereon, scaled distance equations, i.e., K-factor to determine blast overpressure or other distances, will be shown without the $NEWQD^{1/3}$ (cube root of NEWQD). Therefore as an example, K50 means 50 times the cube root of the NEWQD.

It should be noted that the value of K in English units is approximately 2.52 times greater in value as compared to metric units. The K value given in English or metric units is constant. In English units, K equates to pounds-per-square inch (psi); K(m) (Metric units) equates to kilopascal (kPa).

While blast overpressure is proportional to the cube root of the net explosive weight, fragmentation dispersal does not follow such a relationship. Therefore, different methodologies are applied to determine the fragmentation QDRs.

i. Hazardous Fragmentation Distance Range. The HFDR is the minimum withdrawal distance for protection from hazardous primary and secondary fragments from the potential explosion site and the unprotected population and/or traffic density within the exposed site. For single items, the HFDR does not require the calculation of BODR since HFDR will be greater than corresponding minimum K50. For multiple items, determine the BODR as required.

j. Maximum Fragmentation Distance Range. The MFDR is the range to which hazardous primary and secondary fragments from the PES are not expected to travel beyond the ES posing a threat to the personnel exposed in the open.

NOTE

Do not include fillers that do not contribute to explosive effects, e.g., smokes, dyes, irritants, toxic chemical agents, white phosphorus (WP) and plasticizied white phosphorus (PWP), when determining NEWQD. In such cases the NEW, e.g., burster explosive weight, should be used to determine the HFDR and MFDR and not the outside diameter of the AE of concern.

(1) Determining the HFDR and MFDR by Diameter of AE. Fragmentation QDRs can be determined by the diameter of an unknown or known munition that is either cylindrical, e.g., projectiles or bombs, or a series of cylindrical items such as submunition payload within a dispenser. The diameter of an elongated item is usually taken at right angles to the longer axis. For multiple like or mixed items, use the single item with the greater diameter. The HFDR requires a minimum separation distance of 328 feet (100 meters). The HFDR and MFDR are listed in Table 3-3(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4). If comparing a known item in which the diameter and the net explosive weight are known, but distance by diameter is determined greater than by the net explosive weight, use the larger distance by diameter.

(2) Determining the HFDR and MFDR by Net Explosive Weight of AE. Fragmentation QDRs may also be determined by the NEW of a munition which is also a valid method. Although this method is equally applicable to cylindrical shaped items such as the method by diameter, the NEW method is best suited to munitions that cannot be reasonably considered as elongated cylindrical shapes. Examples would include anti-tank/personnel landmines, fuzes, noncylindical IEDs, and bare explosives. For multiple like or mixed items, use the single item containing the greater amount of explosives. The HFDR requires a minimum separation distance of 328 feet (100 meters). Table 3-4(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4) lists the HFDR and MFDR based on the higher explosive weight for the ranges given.

3-2. CRITERIA TO DETERMINE QDRS. Unless otherwise noted, the BODR, HFDR, and MFDR are applicable to AE located on the surface in the open, or located in a structure or vehicle that are incapable of stopping primary fragments. The criteria to determine the applicable QDRs are normally scenario dependent, and generally require the greater distance by the BODR and the HFDR or MFDR as applicable. These are the minimal QDRs required for nonessential personnel. An event tree analysis shown in figure 3-1 summarizes the criteria and applicable QDR relationship. Figure 3-2 shows the relationship between the QDRs and the exposed site. QDRs do not consider for the potential flight range of propulsion units and will require evaluation on a case-by-case basis.

WARNINGS

Be aware that non-case fragments (rogue fragments) such as nose plugs, suspension lugs, strongbacks, and baseplates, may be projected to distances greater than 10,000 feet (3,048 meters). These distances are normally greater than the primary fragment dispersal range.

Increase the fragmentation distance ranges by 33 percent when intentionally disposing of AE placed in stacks or piles. Detonation of munitions in stacks can project fragments to greater distances than detonation of multiple items arranged in a side-by-side orientation.

Increase the fragmentation distance ranges by 33 percent when explosive ordnance items are stacked or haphazardly piled up as a result of an accident/incident. Detonation of munitions in stacks can project fragment ranges to greater distances than the detonation of multiple items arranged in a side-by-side orientation.

Ensure that all personnel located at the Hazardous Fragmentation Distance Range are afforded adequate frontal and overhead protection against the effects of the explosion. At this distance, personnel remaining in the open may incur injury or death from being struck by a hazardous fragment(s). Risks associated with explosion effects increase for distances closer than the hazardous fragmentation distance range.

Ensure personnel are advised to remain away from exterior windows when located at the Hazardous Fragmentation Distance Range. Flying and/or falling glass hazards are expected at this distance range.

NOTE

Protective measures that effectively suppress blast and fragment effects may be used to reduce the BODR, HFDR, or MFDR.

a. QDRs for Unintentional/Accidental Detonations. Incident operations that do not include the intentional detonation of the AE threat. Includes incident circumstances or operational evolutions that do not present an unacceptable risk that may result in an unintentional or accidental detonation of the AE threat. Includes operational procedures, e.g., application of specialized EOD tools and/or techniques that beyond a reasonable doubt, would not result in an unintentional detonation of the AE threat. Applicable to HD 1.1, HD 1.2, or HD 1.5, or mixture of HD 1.1, HD 1.2, and HD 1.5 with any other HD.

(1) For nonessential personnel exposed in the open, use the greater of K50 (K(m)19.84) or the HFDR, with a minimum of 328 feet (100 meters). This distance range is also recommended for essential personnel whenever possible.

(2) For essential personnel in the open, QDRs will be determined by an on-site authority. A minimum of 328 feet (100 meters) withdrawal distance is recommended.

b. QDRs For Intentional/Anticipated Detonations. Incident operations that include the intentional detonation of the AE threat. Includes circumstances or operational evolutions that do present an unacceptable risk that may result in an unintentional or accidental detonation of the AE threat. Includes operations, e.g., application of specialized EOD tools and/or techniques that may result in an unintentional detonation of the AE threat. Applicable to HD 1.1, HD 1.2, or HD 1.5, or mixture of HD 1.1, HD 1.2, and HD 1.5 with any other HD.

(1) For AE involved in a fire, AE involvement is imminent, or if the fire is or may become uncontrollable, use the emergency withdrawal distances listed in table 3-5 as applicable for the HD involved. If personnel cannot be moved to the maximum safety distance range in a safe and timely manner, proceed to paragraph 3-2. b(4). For a known amount of AE, the BODR, HFDR, or MFDR may be used to substitute withdrawal distances listed in table 3-5.

(2) For essential and nonessential personnel exposed in the open, use the greater of K328 (K(m)130.1 or the MFDR, with a minimum of 1,250 feet (381 meters).

(3) For essential personnel with adequate frontal and overhead protection against explosion effects, use the greater of K50 (K(m) 19.84) or the HFDR with a minimum of 328 feet (100 meters).

(4) Incident circumstances, e.g., Category A, that do not permit an orderly, safe, or timely evacuation. Circumstances that pose an unreasonable risk to personnel/public while in the open attempting to evacuate to a maximum QDR. For nonessential/essential personnel/public, use the greater of the K50 (K(m) 19.84) or the HFDR, with a minimum of 328 feet (100 meters). At this distance range, unstrengthend buildings, e.g., wood frame, steel siding, or standard masonry, are not expected to sustain severe structural damage or collapse from blast overpressures. However protection from fragmentation and flying/falling glass hazard effects will be limited. If personnel withdraw to take shelter within such structures at the HFDR, they must remain away from exterior walls and glass windowpanes.

c. QDR Criteria for AE Configured in Stacks/Piles. For detonations involving stacks of AE, or AE haphazardly piled up as a result of accident, the HFDR and MFDR must be increased by 33 percent (multiply by 1.33). For multiple mixed items, evaluate each munition separately and select the greater distance range provided by the single item that has the greater diameter or the greater NEW content.

d. QDR Criteria for HD 1.3, HD 1.4 or HD 1.6 AE.

(1) Incidents or operations that do not include the intentional burning or circumstances/operations that would not result in an unintentional/accidental ignition.

(a) For nonessential personnel, refer to table 3-6 for minimal withdrawal distances.

(b) For essential personnel, to be determined by on-site authority.

(2) Incidents or operations that include the intentional burning or circumstances/operations that may result in an unintentional/accidental ignition. Includes operations, e.g., application of specialized EOD tools and/or techniques that could result in an unintentional ignition of the AE of concern.

(a) For nonessential personnel, NEWQD of 450 pounds (204 kilograms) or less, use a minimum of K50 (K(m) 19.84). For NEWQD greater than 450 pounds (204 kilograms), use a minimum of HFDR as determined using the NEW method.

(b) For essential personnel, withdrawal distances will be determined by on-site authority.

3-3. QDR CRITERIA FOR SINGLE BURIED ORDNANCE ITEM. Table 3-7(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4), (Sheet 5) lists maximum debris and overpressure distances as a function of the NEW at various burial depths. To avoid misidentifying a particular soil composition, the debris and overpressure distances are based on a soil condition that would require the greater maximum distance range. In addition, table 3-8(Sheet 1), (Sheet 2), (Sheet 3) lists QDRs for protection against ground shock for AE located in an underground storage facility. Tables 3-8(Sheet 1), (Sheet 2), (Sheet 3) list distances to protect against ground shock for buried AE. There are three soil compositions listed to determine which distance range applies. Distances given are minimal distances for protection against severe damage to residential/public buildings.

3-4. QDR FOR FLYROCK INCIDENTS. When EOD operations involve the demolition of AE located within a makeshift underground storage area such as a cave or tunnel, a risk analysis should be conducted to determine if a flyrock event is likely. Size-up factors would include the type and amount of AE involved, the relationship between the PES and the overburden known as the critical cover thickness cover (CCT) for potential surface breach, and withdrawal distance to establish an ES for an anticipated flyrock event. There are four likely flyrock scenarios that may be encountered.

a. The PES may be located within a shallow cavern or cave as shown in figure 3-3. It is anticipated that since the CCT extends beyond the free face, flyrock dispersal would likely originate from the free face area.

b. The PES may be within the deep cave/tunnel figure 3-4, but have a shallow ceiling or wall resulting in the hilltop (bench) or sidewall breach. In addition if the free face has an overhang, earth movement or ground shock could cause an overhang to be heaved forward.

c. The PES may be located in a cave or tunnel that has sufficient CCT to prevent ceiling or sidewall breach. However overpressure gases could flow through natural cracks or fissures figure 3-5 in the overburden projecting rock/debris through vents or other surface openings.

d. The PES may present multiple exposures in addition to insufficient CCT such as a thin interior dividing wall figure 3-6 separating two chambers. Thus an explosion at the PES of concern could cause a chain reaction event resulting in a ceiling and/or wall breach as well as a dividing chamber wall breach. In this scenario, rock spall impacting AE in the secondary PES could cause an immediate or delayed detonation for AE effected. A detonation at the secondary PES in turn, could create an additional ceiling or wall breach event if the CCT is less than desired.

e. Determining CCT. The CCT is the relationship between the net explosive weight of the AE involved and the overburden/thickness of the ceiling, walls, and/or walls separating adjacent chambers. The CCT (hemispherical in shape), is an area of coverage where the PES is located, in the bottom center and the lower base line of the CCT and is oriented along the cave/tunnel floor. The CCT measurement should be taken from the interior ceiling and/or walls to the outside surface. The CCT is determined by the equation K3.5 (K(m)1.39). Table 3-9 lists CCT derived from explosive amounts listed. Remember to include disposal explosives into the NEWQD. If it is determined that the overburden or wall thickness is less than the calculated CCT, then anticipate a flyrock event.

f. QDR for Flyrock Event. If a flyrock event is anticipated, use the flyrock withdrawal distance equation K625 (K(m)248). Table 3-9 lists the maximum potential flyrock throw distances derived from the explosive amount listed. Be sure to include disposal explosives as required when determining the NEWQD.

g. QDR for Cave or Tunnel Openings or Portholes. Unless barricaded , it is recommended that personnel withdraw a minimum of 1,800 feet (549 meters), within 10 degrees to either side of the centerline axis of any opening and/or porthole unless means are provided to stop or control flyrock or debris projection from such openings.

h. QDR for AE Energetic Liquids. For AE that requires the use of energetic liquids, or energetic liquids involved in an accident, refer to table 3-10 for recommended minimal withdrawal distances. When the quantities of energetic liquids are given in gallons/liters, conversion factors given in table 3-10 may be used to determine the quantity in pounds/kilograms.

i. Explosive Potential of Flammable Gas-Air Mixtures. The TNT equivalents for select flammable gases show in table 3-11 are based upon heats of reaction rather than field measurements. The heat derived from most gas-air mixtures may be much greater than TNT, but depends upon an ideal fuel-air mixture. The gas must be mixed with air to form explosive mixtures and the mixture reaction must be within the detonation limits. Generally, the gas response for the TNT-equivalent ratios will react as a combination of detonation and combustion. Fuel-air mixtures within structures or other confined areas where the flammable gases collect, can result in a detonation shock wave causing damage and injury. Fragmentation is also likely depending upon the type of containment vessel and surrounding material in close proximity to the PES.

3-5. MITIGATION TECHNIQUES AND PROTECTIVE MEASURES TO REDUCE EXPLOSION EFFECTS.

a. The purpose of mitigation techniques it to eliminate or reduce the probable explosion effects in the event of a detonation. Protective works may be used to suppress blast and fragmentation effects as well as to reduce earth shock. Trenching, venting, and buttressing are some effective methods that reduce earth shock though they can be laborious and time-consuming unless the scenario permits the use of heavy construction equipment. Barricading and buttressing of nearby structures may reduce fragment dispersal and ground shock, but be limited in controlling blast overpressure effects.

b. Mitigation techniques should always be considered when dealing with an AE threat that endangers important facilities and when the EOD team decides to observe a waiting period, as in the case of a Category B incident. Materials may include sandbags, earth, bales of hay, or any other materials that provide defined levels of eliminating or reducing the explosive effects. Where extensive protective works are required, the assistance of construction or engineer personnel/specialists should be obtained.

c. Personnel and Material/Facilities. Protection for personnel and material from explosion effects include the following actions:

(1) Eliminate or establish positive controls of ignition and initiation stimuli to AE of concern.

(2) Use QDRs to protect personnel from explosion effects.

(3) Implement mitigation techniques to lessen or eliminate the threat to personnel and material/structures from explosion effects.

(4) Use protective clothing and hearing protection as required for personnel.

d. Marking the PES and ES. The PES and ES should be plotted on a scaled map. All applicable QDRs should be shown. Access points to and from the ES should be identified and secured as required to prevent personnel and/or vehicular traffic from entering the ES. Evacuation routes should also be noted as well as aircraft flying and landing zones as required.

e. Frontal and Overhead Protection Material. The ability to predict fragment penetration through a target material is a function of fragment striking velocity, weight, and the properties of the target material. Table 3-12 lists select materials that may be used to provide frontal and overhead protection. The materials and required thickness are conservative, when applied at the HFDR. Overhead protection requires special attention in relation to flyrock. Large rocks/boulders tend to fall from higher angles, thus robust overhead protection such as heavy concrete with sturdy walls to support a massive impact, should be sought whenever possible. Typical motor vehicles and residential type buildings do not normally provide adequate frontal and overhead protection against explosion effects especially when the PES is in the line-of-site.

WARNING

Use caution when marking a buried UXO when the type-by-function is in question and/or its depth is questionable. Driving a stake or similar holding device into the surface at the point over the estimated location of a buried UXO could initiate sensitive fuzing or impact the UXO itself causing it to detonate.

f. Marking a Buried UXO. When the existence of a buried UXO has been verified, and the probable size, type, as well as the approximate underground location has been established, its location should be plotted on a map or equivalent. In addition, an ES should be established in order to implement protective measures in the event the UXO should detonate. Table 3-7(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4), (Sheet 5) provides anticipated debris ejection as well as overpressure values to establish an ES and QDRs is required. Physically marking the PES area to note the approximate location of the UXO as required for further action. This can be accomplished using surveyor florescent colored tapes or spray paints.

NOTE

Trenching can protect against underground shock as well as a buttress can. The decision to buttress or trench depends on which system may be more readily constructed.

(1) Trenching. Trenching Figure 3-7 may be used to reduce the probability of earth-shock rupturing or breaking underground installations such as pipelines, cables, building foundations, and underground supports. Trenching interrupts the shock wave which travels through the earth should a buried UXO explode.

(a) Before trenching can be used as a means of protection against earth-shock damage, two conditions must be satisfied. The exposure of concern must be located outside the probable crater area to be expected and located within the radius for earth-shock damage.

(b) Identify any critical or potentially dangerous utilities before conducting trenching operations. The trench should be dug as close as possible to the installation to be protected and must be deep enough so that it extends 24 inches (610 millimeters) or more, below the installation. Use heavy equipment such as a backhoe when possible, as manual digging is time consuming and inefficient. A backhoe bucket provides sufficient trench width. Usually the trench requires no shoring unless there is danger of a cave-in due to excessive trench depth or instability of soil. However, there must be no cross bracing that would transfer the earth-shock across the trench, thereby defeating its purpose.

(2) Buttressing.

(a) This system of protective works involves placing sandbags or timber against the walls and foundations of structures in such a manner as to support them internally and strengthen them externally against the shock of a nearby explosion. Figure 3-8 illustrates buttressing with sandbags.

(b) To protect against underground shock, buttresses should be constructed in basements from the floor up to the ground level. The buttress should be at least 10 feet (3.1 meters) wide at its base, and should taper between 48 and 60 inches (1.2 and 1.5 meters) wide at ground level. A buttress (sandbags or timber) must not extend to the opposite wall, for if so constructed, it will not absorb earth shock, but will transmit the shock to the opposite wall. When sandbags are used, they must be interlocked.

(c) Where the necessary timber is available, bracing or shoring of threatened walls may be more readily accomplished than buttressing with sandbags. Timber should not be less than 4 by 4 pieces. A carpenter, an engineer, or damage control personnel can provide valuable assistance in constructing an effective timber shoring.

g. Sandbag Mitigation and Barricade Techniques.

(1) A surface barricade may be constructed to minimize the effects of blast, fragmentation, and flying debris against a surface installation. Barricades will provide protection above ground only; they will not reduce earth-shock. These measures are applicable to either buried or unburied AE, and are quite readily applicable to small ordnance.

(2) For small ordnance, sandbag explosion effects mitigation technique can permit the AE threat to be blown in place. It is preferable to use fabric woven polypropylene sandbags filled with clean dry sand. Wet sand may produce voids within a sandbag. Four walls of identical thickness should surround the munition. Refer to table 3-13 for minimal wall thickness for select size munitions. Arrange sandbags around munition as follows:

NOTE

This procedure is limited to munitions up to 155-mm (6.00 inches) in diameter similar in design and net explosive weight to the US M107 projectile.

At a minimum, a double layer of sandbags shall be used. If a 12-inch (305-millimeter) thickness is required, position in order that two sandbags are necessary to achieve this thickness.

(a) Maintain a clear standoff of 6-inches (152-millimeters) figure 3-9 between the munition and the inside face of each wall and ceiling while placing sandbags in position.

(b) Build walls so that the interior face of each wall is vertical; the outside may have a 1:6 (2-inch horizontal to 12-inch (51-305-millimeter) vertical) slope.

(c) Position sandbags tightly in place with vertical joints staggered. The munition should not be visible through any portion of the sandbag wall.

(d) As each wall is built, each new layer of sandbags should run in opposite direction to the layer below, so that the layers are interlocked.

(e) After each side wall is built to approximately 6-inches above the munition, position disposal charge as required.

(f) Prepare a piece of 3/4-inch thick or greater of plywood or equivalent, by cutting it so that is dimensions are approximately 12-inches (305 millimeters) greater on each side than the standoff distance between the munition and the inside walls.

(g) Place plywood on top of the walls and stack sandbags with staggered horizontal joints and alternating directions in each layer on top of plywood ceiling. Sandbag positioned on top of the plywood roof must be the same height as the side wall thickness.

h. Taping of glass. Taping glass windows and skylights may provide protection against flying glass caused by overpressure effects. Tarpaulins, blankets, and bedding may also be used.

i. Venting.

(1) A shaft sunk directly over the UXO will permit the explosion to vent upwards through the shaft, and will greatly reduce the earth-shock. Figure 3-10 illustrates the method of venting a UXO near a structural foundation. Venting is a difficult and hazardous operation. It should never be used in areas where blast, fragmentation, and earth debris effects would constitute a serious threat. An accurate estimate of the subsurface position of the UXO is essential.

(2) In EOD operations where shafting is used to gain access to the UXO, that shaft automatically provides a vent. In instances where the upward venting of the explosive force is not dangerous, the UXO may be blown in place in the shaft.

j. Mounding. Mounding or covering an ordnance item for the intention detonation/disposal may be done depending upon the AE involved. Table 3-7(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4), (Sheet 5) may be used to determine burial depths required to reduce the explosion effects of a single item detonation. Only clean soil (free from rocks or other debris) should be used for tamping. In selecting a disposal site, table 3-8(Sheet 1), (Sheet 2), (Sheet 3) provides separation distances for ground shock effects.

k. Time Interval Between Intentional Detonations. To prevent blast waves from coalescing (coming together to form one blast wave) during the detonation of two or more stacks of AE, maintain a minimum one second delay between each shot initiation. Another method to determine time interval is by the equation TI=K7 x NEWQD^1/3 (K(m)2.8). Where TI is time interval in milliseconds, K is the multiplying factor times the cube root of the greater NEWQD stack involved.

l. Separation Distances Between Two or More Skacks of AE. Observe the following separation distances between two or more AE stacks for disposal operations.

(1) Non-barricaded stacks. Use a minimum of K18 x NEWQD^1/3 (K(m)7.1).

(2) Barricaded stacks. Use a minimum of K9 x NEWQD^1/3 (K(m)3.6).

m. Barricades. Barricades may be used between two or more disposal sites to prevent an unwanted propagation from one disposal site to another. Barricades can reduce low-angle fragments and reduce overpressure loads at or very near the barricade. However, barricades do not provide protection against high-angle fragments or kick-outs. In addition, care must be taken not to construct a barricade with material that would produce secondary fragments or debris.

(1) Barricade design for protection against high-speed, low-angle fragments.

(a) Location. Barricades may be located anywhere between the PES and the ES. The location will determine the height and length of the barricade.

NOTES

To avoid building excessively high barricades, the location of the barricade should be located as close as possible to the AE stack on which the reference point was established.

When AE stacks are of equal height, the reference point may be established on either stack. If the tops of the two stacks are not of equal height, the reference point will be on the top of the lower stack.

(b) Height. To determine the barricade height, establish a reference point at the top of the far edge of one of the two AE stacks figure 3-11 between which the barricade is to be constructed.

(c) Draw a line from the reference point to the highest point of the other stack.

(d) Draw a second line from the reference point forming an angle of two degrees above the line.

(e) Length. Refer to figure 3-11 for length specifications.

(2) Barricade design for the protection against overpressure.

(a) Location. Barricade standoff shall be within double the barricade height of the area to be protected.

(b) Height. The top of the barricade should be at least as high as the top of the protected area.

(c) Length. The length of the barricade should be at least two times the length of the area to be protected.

n. Multiple item detonations. In order to reduce projection distances for disposal of AE, the preferred method is to place munitions in a single layer with their sides touching so that their axis is horizontal. Orient munitions so that suspension lugs, strongbacks, and nose or tail baseplates are facing away from areas to be protected. Detonate all munitions simultaneously.

APPENDIX A.

1. Table A-1 lists blast overpressure, fragmentation distance range equations used in this manual.

2. Calculating the volume of an unknown item in order to estimate it's potential net explosive weight, can be accomplished in order to determine QDRs. Typical geometric shapes along with corresponding volume equations are shown in Figure A-1(Sheet 1), (Sheet 2) Once the cubic volume of a container is calculated, refer to table 3-1(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4) and select the explosive of choice where the density is shown. Multiply the density by the cubic inches for the weight in pounds; convert to metric units as required.

3. Visit the Department of Defense Explosive Safety Board (DDESB) website for the blast effects computer on the secure site. Other explosive safety information resources are also available at this site.

APPENDIX B. TERMINOLOGY AND DEFINITIONS. The following are common terms and definitions used throughout this manual.

Ammunition and Explosives (AE). Includes all categories of ordnance, unexploded ordnance (UXO), or improvised explosive device (IED) to include large improvised explosive devices (LIED) and large vehicle improvised explosive devices (LVIED).

AE Classification Divisions and Compatibility Groups. The Department of Transportation (DOT) hazardous materials regulations 49 CFR 171 to 177 define classification divisions or hazard divisions (HD) for explosive materials. In addition, there are thirteen compatibility groups (CG) assigned to AE based on similarity of function, features, and accident effects potential. Hazard divisions are shown on shipping papers and on labels or placards for transportation and storage purposes. The HD and/or CG assists in identifying the hazard nature of ammunition and explosives and aid to determine the effects should AE be involved in transportation and/or storage incident.

AE Divisions include:

HD 1.1 (mass-explosion)

HD 1.2 (non-mass explosion, fragment producing). HD 1.2 has an additional three sub-divisions, i.e., 1.2.1, 1.2.2, and 1.2.3 that are applicable for storage configurations only

HD 1.3 (mass fire, minor blast or fragment)

HD 1.4 (moderate fire, no significant blast or fragment)

HD 1.5 (explosive substance, very insensitive with mass-explosion hazard)

HD 1.6 (explosive article, extremely insensitive.

Storage and Transportation Compatibility Groups include:

Group A. Bulk initiating explosives that have the necessary sensitivity to heat, friction, or shock to make them suitable for use as initiating elements in an explosive train. Examples include bulk lead azide, lead styphnate, mercury fulminate, tetracene dry cyclonite (RDX) and dry pentaerythritol tetranitrate (PETN).

Group B. Detonators and similar initiating devices not containing two or more effective protective features. Items containing initiating explosives that are designed to initiate or continue the functioning of an explosive train. Examples include detonators, blasting caps, small arms primers, and fuzes.

Group C. Bulk propellants, propelling charges, and devices containing propellant with, or without, its own means of initiation. Examples include bulk single-, double-, or triple-based composite propellants, solid propellant rocket motors, and propelled ammunition and explosives with inert projectiles.

Group D. Bulk black powder, high explosives, and ammunition without a propelling charge, but containing high explosives without its own means of initiation, i.e., no initiating device is present or the device has two or more effective protective features. Examples include bulk TNT, Composition B, and black powder, bulk wet RDX or PETN, bombs, projectiles, cluster bomb units, depth charges and torpedo warheads.

Group E. AE containing high explosives without its own means of initiation and either containing, or with, a solid propelling charge. Examples include artillery rocket assisted ammunition, rockets, and guided missiles.

Group F. AE containing high-explosives with its own means of initiation, i.e., the initiating device present has less than two effective protective features, and with or without a solid propelling charge. Examples include grenades, sounding devices, and similar items having explosive train with less than two effective protective features.

Group G. Illuminating, incendiary, and smoke (including HC) or tear-producing AE excluding those that are water-activated or that contain white phosphorus (WP) or a flammable liquid or gel. Examples include flares, signals, and pyrotechnic substances.

Group H. AE containing WP. AE in this group contains fillers that are spontaneously flammable when exposed to water or the atmosphere. Examples include WP and plasticizied white phosphorus (PWP).

Group J. AE containing flammable liquids or gels other than those that are spontaneously flammable when exposed to water or the atmosphere. Examples include liquid-or gel-filled incendiary AE, fuel-air explosive devices, and flammable liquid-fueled missiles and torpedoes.

Group K. AE containing toxic chemical agents. AE in this group contains chemicals specifically designed for incapacitating effects more severe than lachrymation (tear-producing). Examples include artillery or mortar AE (fuzed or unfuzed), grenades, rockets, and bombs filled with a lethal or incapacitating chemical agent.

Group L. AE not included in other CG. AE having characteristics that present a special risk that does not permit storage with other types of AE, or other kinds of explosives, or dissimilar AE of this group. Examples include water-activated devices, pyrophorics and phosphides and devices containing these substances, prepackaged hypergolic liquid-fueled rocket engines, triethyl aluminum (TEA), thickened TEA, and damaged or suspect AE of any group.

Group N. AE containing only extremely insensitive detonating substances (EIDS). An example is HD 1.6 AE.

Group S. AE that presents no significant hazard. AE is packaged or designed so that any hazardous effects from accidental functioning are limited to an extent that they do not significantly hinder fire fighting. Examples include explosive switches or valves, and small arms ammunition.

Blast Overpressure Distance Range (BODR). The overpressure above the ambient pressure in a blast wave at a given distance from the PES. For quantity distance range purposes, overpressure derived from K50, also referred to as the inhabited building distance (IBD), is used for unintentional/accidental detonations. Overpressure distances derived using K328 are used for intentional/anticipated detonations.

Emergency Withdrawal Distance. Distance to which personnel are removed from an ES during an accident or incident when AE of concern is involved in an uncontrollable fire, or fire involvement is imminent.

Explosion Effects. Includes blast overpressure, primary and secondary fragments, heat flux, and firebrand.

Exposed Site (ES). The area exposed to the potential hazardous effects, e.g., fragmentation, blast, secondary debris, or heat flux, should the AE detonate at the

PES.

Hazardous Fragmentation Distance Range (HFDR). Distance to which primary fragment concentration is no more than one per 600 square-foot area. Equates to a 1 percent probability of a person be struck by a hazardous fragment while standing in the open. AE with preformed or scored warheads may produce greater than one per 600 square-foot area. The HFDR is usually applicable to an unforeseen event(s), circumstances, or operational procedures that may result in an unintentional or accidental detonation.

Inhabited Buildings Distance (IBD). Structures other than AE-related buildings, occupied by personnel or the general public, both within and outside Department of Defense establishments. Examples include schools, churches, residential, commercial and industrial complexes, hospitals, quarters, theaters, mess halls, or post offices. For blast overpressure, K50 (distance in feet divided by the cube root of explosives in pounds) is normally the scaled distance requirement.

Loading Density. Quantity of explosive per unit volume expressed as pounds per cubic foot or pounds per cubic inch. If the volume of an unknown container can be estimated, the known density of a specific explosive can be used to estimate the explosive content of the container.

Maximum Fragmentation Distance Range (MFDR). Primary and secondary fragments are not expected to disperse beyond this QDR. Does not include rogue fragments that may disperse far beyond the MFDR. The MFDR is applicable to incidents involving intentional detonations, or circumstances or incident events and/or procedures evolution that may result in an unintentional detonation.

Net Explosive Weight Quantity Distance (NEWQD). The total quantity (by weight) of high explosive including its main charge TNT equivalency, if known, in each AE item to be used when applying QDRs.

Nonessential Personnel. Individual(s) identified by the DOD component, as not associated with an AE operation or accident or incident.

Essential Personnel. Individual(s) identified by a DOD component as associated with an AE operation or accident or incident.

Potential Explosion Site (PES). Location where detonation is imminent or likely to occur.

APPENDIX C. Examples. The following figures provide examples to determine QDRs for BODR, HFDR, and MFDR.

1. Example C-1 Single Item Detonation(Sheet 1), (Sheet 2), (Sheet 3).

2. Example C-2 Multiple Item Detonation(Sheet 1), (Sheet 2), (Sheet 3), (Sheet 4).

3. Example C-3 Unknown UXO.

4. Example C-4 IED Incident.

Table A-1. Blast Overpressure and Fragmentation Equations.

English Units	Metric Units
Blast Overpressure Distance Range (BODR) (Scaled Distance) $D=K \times W^{1/3}$ D = distance in feet K = multiplying factor in English units $W^{1/3}$ = cube root of NEWQD in pounds	**Blast Overpressure Distance Range (BODR) (Scaled Distance)** $D=K(m) \times Q^{1/3}$ D = distance in meters K(m) = multiplying factor in Metric units $Q^{1/3}$ = Cube root of NEWQD in kilograms
Hazardous Fragmentation Distance Range (HFDR) In Feet **Determined by diameter of an item:** $142.2 \times D^{0.68}$ 142.2 = multiplying factor $D^{0.68}$ = diameter in inches raised to 0.68 power **Determined by NEWQD of an item:** $315.9 \times W^{0.164}$ 3.15 = multiplying factor $W^{0.164}$ = NEWQD in pounds raised to the 0.164 power	**Hazardous Fragmentation Distance Range (HFDR) In Meters** **Determined by diameter of an item:** $4.81 \times D^{0.68}$ 4.81 = multiplying factor $D^{0.68}$ = diameter in millimeters raised to 0.68 power $23.0 \times D^{0.68}$ 23.0 = multiplying factor $D^{.068}$ = diameter in centimeters raised to .068 power **Determine by the NEWQD of an item:** $109.62 \times Q^{0.164}$ 109.62 = multiplying factor $Q^{0.164}$ = NEWQD in kilograms raised to the 0.164 power
Maximum Fragmentation Distance Range (MFDR) In Feet **Determined by diameter of an item:** $854.8 \times D^{0.682}$ 854.8 = multiplying factor $D^{0.682}$ = diameter in inches raised to 0.682 power **Determined by NEWQD of an item:** $2756 + 565.9 \times \ln(NEWQD)$ ln(NEWQD) = natural logarithm of (NEWQD) in pounds	**Maximum Fragmentation Distance Range (MFDR) In Meters** **Determined by diameter of an item:** $28.70 \times D^{0.682}$ 28.70 = multiplying factor $D^{0.682}$ = diameter in millimeters raised to the 0.682 power $138.0 \times D^{0.682}$ 138.0 = multiplying factor $D^{0.682}$ = diameter in centimeters raised to the 0.682 power **Determined by NEWQD of an item:** $976.4 + 172.5 \times \ln(Q)$ ln(NEWQD) = natural logarithm of NEWQD in kilograms
Determine K-Factor: K-Factor = known distance range/$NEWQD^{1/3}$ K-factor = Scaled distance range multiplying factor known distance range = known distance in feet $NEWQD^{1/3}$ = cube root of NEWQD in pounds	**Determine K(m):** K(m) = known distance range/$NEWQD^{1/3}$ K(m) = Scaled distance range multiplying factor known distance range = known distance in meters $NEWQD^{1/3}$ = cube root of NEWQD in kilograms

Table A-1

TABLE A-1 BLAST OVERPRESSURE AND FRAGMENTATION EQUATIONS

Single Item Detonation.

NOTES

This example shows how to determine the BODR, HFDR, and the MFDR. Shown are where and how information is obtained from tables, and if preferred, how to perform calculations using equations. A calculator capable of performing cube root ($\sqrt[3]{}$ or $n^{1/3}$), exponent (x^y or x^y), and natural logarithm (ln) functions is required to do equations.

This example is for a known item, i.e., both diameter and net explosive weight (NEW) are known. Equations and conversions are shown in both English units (in black) and Metric units (highlighted in yellow).

a. M437A1 175-mm Projectile (1 each).

(1) Diameter 6.89-inches (175-mm)

(2) Net explosive weight: 31 lbs (14.06-kg)

Explosive composition: Comp. B with a TNT equivalent 1.16

b. Since the NEW and the TNT equivalent are known, the NEWQD is determined by:

English Units	(Metric Units)
31 pounds x 1.16 = 35.96 lb	(14.06 kg x 1.16 = 16.31 kg)

c. Blast overpressure distance range (BODR) is determined by:

NOTES

For this example, both the BODR K328 and K50 will be determined by working the equation. Otherwise see table 3-3 or 3-4 for estimated BODR.

The K-factor in English units is $KW^{1/3}$; where K is the constant multiplying factor in English units, $W^{1/3}$ is the cube root of the NEWQD in pounds. The K-factor in metric units is, $K(m)Q^{1/3}$; where K(m) is the constant multiplying factor in Metric units, and $Q^{1/3}$ is the cube root of the NEWQD in kilograms.

English units	(Metric Units)
BODR = K328 x $35.96^{1/3}$ = 328 x 3.30 = 1,083 ft	BODR = (K(m) 130.1 x $16.31^{1/3}$) = (130.1 x 2.54) = (330 m)
BODR = K50 x $35.96^{1/3}$ = 50 x 3.30 = 165 ft	BODR = (K(m) 19.84 x $16.31^{1/3}$ = (19.84 x 2.54) = 50 m

Example C-1. Single Item Detonation (Sheet 1 of 3).

Table C-1:1

EXAMPLE C-1. SINGLE ITEM DETONATION (SHEET 1 OF 3)

Single Item Detonation - Cont.

d. Determine the Hazardous Fragmentation Distance Range (HFDR) as follows:

(1) The item by diameter: 6.89 inches (175-mm)

(a) HFDR derived from table 3-3: 534 ft (163 m)

(b) HDFR derived by equation work:

English Units	(Metric Units)
$HFDR = 142.2 \times D^{0.68}$	$HFDR = (4.81 \times D^{0.68})$
$= 142.2 \times 3.715$	$= (4.81 \times 33.517)$
$= 528$ ft	$= (161$ m$)$

(2) The NEWQD of the item: 35.96 lbs (16.31 kg)

(a) HFDR derived from table 3-4: 578 ft (176 m)

(b) HFDR derived by equation work:

English Units	(Metric Units)
$HFDR = 315.9 \times W^{0.164}$	$HFDR = (109.62 \times Q^{0.164})$
$= 315.9 \times 1.79$	$= (109.62 \times 1.58)$
$= 568$ ft	$= (173$ m$)$

NOTE

When only a single item is involved, the HFDR can be used in lieu of the minimal K50 BODR.

Example C-1. Single Item Detonation (Sheet 2 of 3).

Table C-1:2

EXAMPLE C-1. SINGLE ITEM DETONATION (SHEET 2 OF 3)

Single Item Detonation - Cont..

e. Determine the Maximum Fragmentation Distance Range (MFDR) as follows:

(1) MFDR determined by the diameter of the item: 6.89 inches (175-mm).

(a) MFDR derived from table 3-3: 3,223 ft (983 m)

(b) MFDR derived by equation work:

English Units	(Metric Units)
$MFDR = 854.8 \times D^{0.682}$	$MFDR = (28.70 \times D^{0.682})$
$= 854.8 \times 3.729$	$= (28.70 \times 33.865)$
$= 3{,}188$ ft	$= (972$ m$)$

(2) HFDR by NEWQD of the item: 35.96 lb (16.31 kg)

(a) MFDR derived from table 3-4: 4,843 ft (1,476 m)

(b) MFDR derived by equation work:

English Units	(Metric Units)
$MFDR = 2756 + 565.9 \times \ln(W)$	$MFDR = (976.4 + 172.5 \times \ln(Q)$
$= 2756 + 565.9 \times 3.58$	$= (976.4 + 172.5 \times 2.79)$
$= 4{,}783$ft	$= (1{,}458$ m$)$

f. Results: Apply QDRs as required for scenario at hand.

NOTE

Since this is a known item where the HFDR and MFDR can be determine by either the diameter of the item or by its net explosive weight, use the greater distance derived by NEWQD. However the HFDR or MFDR QDR as determined by diameter would be acceptable. So if you can identify the item, but cannot remember or determine its net explosive weight, you still have an acceptable method to determine a QDR. HFDR and MFDR QDRs shown below were derived from tables 3-3 and 3-4. Results from equation work are equally acceptable.

(a) Intentional/Anticipated Detonation (greater of BODR or MFDR):

(1) BODR = 1,122 ft (342 m)

(2) MFDR = derived by NEWQD of the item: 4,843 ft (1,476 m)

(b) Unintentional/Accidental Detonation (greater of BODR or HFDR, with minimum of 328 ft (100 m)):

(1) BODR = 171ft (52 m) for essential personnel; 328 ft (100 m) minimum for nonessential personnel.

(2) HFDR = Derived by NEWQD of the item: 578ft (176 m)

Example C-1. Single Item Detonation (Sheet 3 of 3).

Table C-1:3

EXAMPLE C-1. SINGLE ITEM DETONATION (SHEET 3 OF 3)

Unknown Item on the Surface.

a. EOD team on-site is unable to identify an UXO item. During reconnaissance, it has been determine that subject item is elongated cylindrical in shape, 14-inches in diameter and main body length of approximately 36 inches. The item appears to be a bomb. The bomb has what appears to be an impact nose fuze; there are no provisions for a tail fuze. There are no markings to identify country of origin or its explosive composition and weight. Chemical is not suspected. What are the QDR options?

NOTES

If a QDR is required prior to EOD team arrival, apply minimum of 1,250 feet as the initial exposed site (ES).

For this example, all measurements are in inches.

(1) Option 1. Use table 3-3 by diameter of the item to derive and/or adjust the initial ES QDR using the applicable BODR, HFDR, or MFDR as required.

(2) Option 2. Do a conservative estimate the new explosive weight of the item by determining the volume of a cylinder. Volume of a cylinder is determined by 3.14 x the radius square (half of the greater diameter of the bomb body) x its length, say 36 inches. Since the nose end is conical in shape, approximately 6-inches is deleted from overall length.

$$\begin{aligned} \text{Volume} &= 3.14xr^2L \\ &= 3.14 \times 49 \text{ (7 inches squared) x 36 inches long} \\ &= 5{,}539 \text{ cubic inches} \end{aligned}$$

(a) Go to table 3-1 to select an explosive to obtain a loading density. Remember that when determining the net explosive weight quantity distance (NEWQD), use not less than the TNT equivalent of TNT or 1. In this example, the density for TNT will be used. TNT density is 0.0592 pounds per cubic inch.

Conservative estimated NEWQD = TNT density x estimated volume of the subject item.

$$\begin{aligned} \text{NEWQD} &= \text{Explosive density/volume} \\ &= 0.0592 \times 5{,}539 \\ &= 328 \text{ pounds} \end{aligned}$$

(b) Based on the estimated NEWQD, use table 3-4 or work equations to establish and/or adjust the initial ES QDR using the applicable BODR, HFDR, and MFDR as required.

Example C-3. Unknown UXO on the Surface.

Table C-3

EXAMPLE C-3. UNKNOWN UXO ON THE SURFACE

Intentional Detonation of Multiple Mixed Items.

NOTES

This example shows how to determine the BODR, HFDR, and the MFDR. Shown are where and how information is obtained from tables, and if preferred, how to perform calculations using equations. A calculator capable of performing cube root ($\sqrt[3]{}$ or $n^{1/3}$), exponent (x^y or x^y), and natural logarithm (ln) functions is required to do equations.

This example is for known items, i.e., both diameter and net explosive weight (NEW) are known. Equations and conversions are shown in both English units (in black) and Metric units (highlighted in yellow).

a. Items include M19 AT landmines (50 each), M101 155-mm projectiles (70 each), and Mk 82 bombs (12 each).

(1) M19 landmines: Diameter, not applicable (not considered an elongated cylindrical item). NEW per mine: 21 lb, of Composition B (TNT equivalent 1.16) with an NEWQD of 24.36 lb (11.05 kg) each with a total NEWQD of 1,218 lb (552 kg).

(2) M101 projectiles: Diameter of 6 inches (155 mm). NEW per projectile 15.5 lb (7.03 kg) of TNT (TNT equivalent 1) with an NEWQD of 15.5 lb (7.03 kg) each with a total NEWQD of 1,085 lbs (492 kg).

(3) Mk 82 bombs: Diameter of 10.8 inches (274mm). NEW per bomb 192 lbs (87.1 kg) of H-6 (TNT equivalent 1.38) with an NEWQD 265 lb (120.2 kg) each with a total NEWQD of 3,180 lbs (1,442 kg).

(4) Disposal explosives: 20 lbs (9.07 kg) of C-4 (TNT equivalent 1.37) with a total NEWQD of 27.4 lbs (12.43 kg).

b. Total NEWQD: 5,510.4 lbs (2,500 kg).

c. Blast Overpressure Distance Range (BODR) is Determined as Follows.

NOTES

In this example, both the BODR K328 and K50 will be shown.

The K-factor in English units is $KW^{1/3}$; where K is the constant multiplying factor in English units, $W^{1/3}$ is the cube root of the NEWQD in pounds. The K-factor in metric units is, $K(m)Q^{1/3}$; where K(m) is the constant multiplying factor in Metric units, and $Q^{1/3}$ is the cube root of the NEWQD in kilograms.

Figure C-2. Multiple Item Detonation (Sheet 1 of 4).

Table C-2:1

EXAMPLE C-2. MULTIPLE ITEM DETONATION (SHEET 1 OF 4)

Intentional Detonation of Multiple Mixed Items.

c. Blast Overpressure Distance Range (BODR) is Determined as Follows-Cont.

English Units	(Metric Units)
BODR = $K328 \times 5{,}510.4^{1/3}$ = 328×17.66 = 5,793 ft	BODR = ($K(m)\ 130.1 \times 2{,}500^{1/3}$) = ($130.1 \times 13.57$) = (1,766 m)
BODR = $K50 \times 5{,}510.4^{1/3}$ = 40×17.66 = 883 ft	BODR = ($K(m)\ 19.84 \times 2{,}500^{1/3}$ = (15.87×13.57) = (269 m)

d. Determine the Hazardous Fragmentation Distance Range (HFDR) as follows:

NOTE

For mixed munitions, use the largest single item, either by diameter or net explosive weight to determine the HFDR.

(1) The single largest single by diameter: Mk 82 at 10.8 inches (274.3 mm).

(a) HFDR derived from table 3-3: 726ft (221m).

(b) HFDR derived by equation work:

English Units	(Metric Units)
HFDR = $142.2 \times D^{0.68}$ = 142.2×5.043 = 717 ft	HFDR = ($4.81 \times D^{0.68}$) = (4.81×45.498) = (219 m)

(2) The single item having the greater NEW: Mk 82 with a NEWQD of 265 lbs (120.2 kg).

(a) HFDR derived from table 3-4: 805 ft (245 m)

(b) HFDR derived by equation work:

English Units	(Metric Units)
HFDR = $315.9 \times W^{0.164}$ = 315.9×2.496 = 789 ft	HFDR = ($109.62 \times Q^{0.164}$) = (109.62×2.193) = (240 m)

Figure C-2. Multiple Item Detonation (Sheet 2 of 4).

Table C-2:2

EXAMPLE C-2. MULTIPLE ITEM DETONATION (SHEET 2 OF 4)

Intentional Detonation of Multiple Mixed Items.

e. Determine the Maximum Fragmentation Distance Range (MFDR) as follows:

NOTE

For mixed munitions, use the largest single item either by diameter or net explosive weight to determine the MFDR.

(1) The single largest item by diameter: Mk 82 at 10.8 in (274.3 mm).

(a) MFDR derived from table 3-3: 4,386 ft (1,337 m)

(b) MFDR derived by equation work:

English Units	(Metric Units)
MFDR = 854.8 x $D^{0.682}$	(MFDR = (28.70 x $D^{0.682}$)
= 854.8 x 5.067	= (28.70 x 46.014)
= 4,332 ft	= (1,320 m)

(2) The single item having the greater NEW content: Mk 82 with a NEWQD of 265 lbs (120.2 kg).

(a) MFDR derived from table 3-4: 5,984 ft (1,824 m).

(b) MFDR derived by equation work:

English Units	(Metric Units)
MFDR = 2756 + 565.9xln(W)	MFDR = (976.4 + 172.5 x ln(Q)
= 2756 + 565.9 x 5.579	= (976.4 + 172.5 x 4.789)
= 5,914 ft	= (1,803 m)

NOTES

For this example, the greater distance by net explosive weight will be used to determine the HFDR and the MFDR.

Increasing the HFDR and MFDR for stacked items applies to primary fragment dispersal and not to rogue fragments dispersal. Rogue fragments can disperse greater than 10,000 feet (3,048 meters) from the PES.

f. Modifying Condition: Munitions are to be stacked: Increase the HFDR and MFDR by 33% or multiply by 1.33 for primary fragment dispersal.

(1) HFDR: 789 x 1.33 = 1,049 ft (320 m).

(2) MFDR: 5,914 x 1.33 = 7,866 ft (2,398 m).

Figure C-2. Multiple Item Detonation (Sheet 3 of 4).

Table C-2:3

EXAMPLE C-2. MULTIPLE ITEM DETONATION (SHEET 3 OF 4)

Intentional Detonation of Multiple Mixed Items.

NOTE

The greater of K50 or HFDR could be used while preparing the demolition shot since during this part of the operation any detonation would fall under the criteria of an unintentional/accidental detonation.

g. Results. Apply greater of BODR or MFDR for Intentional/Anticipated Detonation for Essential and Nonessential Personnel in the Open.

(1) BODR: Total based on NEWQD: 5,793 ft (1,766 m).

(2) MFDR: Based on NEWQD for stacked/piled items: 7,866 ft (2,398 m).

(3) The MFDR would be the greater QDR for Intentional Detonation.

NOTE

Suppose you wanted to know what the blast overpressure would be at the adjusted MFDR. In this example, the NEWQD is known so an estimate can be done.

h. How to Determine the K-factor and Overpressure Value at the 7,866 ft MFDR.

(1) Scaled distance or K-factor is determine by the equation:

$$\text{K-factor} = \text{known distance range}/\text{NEWQD}^{1/3}$$

Where K-factor is the multiplying factor, known distance range is QDR (in feet; in this example 7,866 ft) and $\text{NEWQD}^{1/3}$ is cube root of NEWQD (in this example the cube root of 5,510.4 lbs is 17.66).

(2) Equation work to determine K-factor:

$$\begin{aligned}\text{K-factor} &= 7{,}866/5{,}510.4^{1/3} \\ &= 7{,}866/17.66 \\ &= 445\end{aligned}$$

(3) See table 2-1 to located the closest K-factor given to determine an estimated blast overpressure value.

(4) A K-factor of 445 would equate to an approximate blast overpressure of 0.04 psi in English units at 7,866 feet or 0.3 kPa in Metric units at 2,398 meters from the demolition site.

Figure C-2. Multiple Item Detonation (Sheet 4 of 4).

Table C-2:4

EXAMPLE C-2. MULTIPLE ITEM DETONATION (SHEET 4 OF 4)

IED Incident.

1. EOD team responds to an IED call.

2. The suspect IED container has a geometric shape of a rectangle.

3. Determine QDRs options.

NOTE

An initial QDR for this incident would be 1,250 feet (381 meters) for all personnel exposed in the open.

a. As required, determine a approximate NEWQD of the subject item to adjust QDR.

(1) The item is 18 inches wide, 6 inches in height, and 36-inches in length

(2) Determine the volume of the subject. (see Appendix A)

(3) The subject item has a volume of 3,888 cubic inches.

(4) Refer to table 3-1 and select an explosive where the density is listed.

(5) For this example, we will use TNT (density = 0.0592 pounds per cubic inch).

(6) Multiply 0.0592 x 3,888 = 230 lbs NEWQD.

b. Go to table 3-4 to, find 230 Pounds in the Ranges given to Determine HFDR, MFDR and BODR.

NOTE

Whenever possible, ensure all personnel are at their applicable QDRs prior to conducting EOD or other operations on the subject item.

(8) Due to the nature of an IED in general, the criteria for an intentional/anticipated detonation would apply. Therefore, unless nonessential personnel are provided adequate protection against explosion effects, the greater of K328 or MFDR would apply.

(9) If nonessential personnel cannot be evacuated to the greater of K328 or MFDR, then the greater of K50 or HFDR may be applied. At these distances, personnel seeking shelter in unstrengthened buildings must remain away from exterior wall and window glass.

Example C-4. IED Incident.

Table C-4

EXAMPLE C-4. IED INCIDENT

Table 2-1. K-Factors and Corresponding Overpressure Values.

Scaled Distance K-Factor K(m)	Overpressure Value Pounds-per-square-inch (psi) (Kilopascal (kPa))	Scaled Distance K-Factor K(m)	Overpressure Value Pounds-per-square-inch (psi) (Kilopascal (kPa))
1000 (397.8)	0.01 (0.09)	60 (23.8)	0.71 (4.93)
800 (317.4)	0.02 (0.13)	55 (21.8)	0.79 (5.47)
700 (277.7)	0.02 (0.16)	50 (19.8)	0.89 (6.17)
625 (248.0)	0.03 (0.18)	45 (17.8)	1.02 (7.04)
600 (238.0)	0.03 (0.19)	40 (15.8)	1.18 (8.16)
550 (218.2)	0.03 (0.22)	35 (13.8)	1.40 (9.66)
500 (198.4)	0.04 (0.25)	30 (11.9)	1.71 (11.80)
450 (178.5)	0.04 (0.29)	25 (9.92)	2.18 (15.06)
400 (158.7)	0.05 (0.34)	20 (7.93)	3.00 (20.67)
350 (138.8)	0.06 (0.41)	15 (5.95)	4.68 (32.25)
328 (130.1)	0.07 (0.45)	12 (4.76)	6.84 (47.14)
300 (119)	0.07 (0.51)	10 (3.96)	9.56 (65.93)
250 (99.2)	0.10 (0.66)	9 (3.57)	11.74 (80.94)
200 (79.3)	0.13 (0.91)	8 (3.17)	14.92 (102.84)
150 (59.5)	0.20 (1.36)	7 (2.77)	19.78 (136.41)
100 (39.6)	0.35 (2.40)	6 (2.38)	27.71 (191.04)
80 (31.7)	0.48 (3.29)	5 (1.98)	41.95 (289.27)
75 (29.7)	0.52 (3.60)	4 (1.58)	70.28 (484.57)
70 (27.7)	0.58 (3.97)	3 (1.19)	134.85 (929.82)
65 (25.7)	0.64 (4.40)	2 (0.79)	313.91 (2,164.53)

Table 2-1
K-FACTORS AND CORRESPONDING OVERPRESSURE VALUES

Table 2-2. Blast Overpressure Effects to Unprotected Ears.

Effect	Incident Overpressure psi (kPa)	Scaled Distance[1] K-Factor (K(m))
Moderate risk of complaints from detonation noise: 110-125 decibels	0.01 (0.068)	1,998.4 (793)
High risk of complaints from detonation noise: 125-139 decibels	0.03 (0.206)	635.4 (252)
Recommended minimal one day exposure from impulsive or impact noise to unprotected ears (equates to an approximate 140 decibels)	0.03 (0.21)	585 (232)
Distinct feeling of fullness in the ears. Increasing discomfort with ear ringing (tinnitus) or hissing, roaring, crackling, snapping character; or annoying "click" which is heard and felt in the ear. May experience pain and mild vertigo.	0.30-0.58 (2.07-3.99)	111-70 (44-28)
Eardrum rupture (1% probability)	3.0 (20.69)	20 (7.93)
Eardrum rupture (5% probability)	3.6 (24.82)	17.9 (7.10)
Eardrum rupture (10% probability	6.6 (45.51)	12.2 (4.84)
Eardrum rupture (20% probability)	9.0 (62.06)	10.3 (4.09)
Eardrum rupture (50% probability	15.0 (103.43)	8.0 (3.17)
Eardrum rupture (99% probability)	74.4 (513)	3.9 (1.55)
Personnel thrown off balance	2.3 (15.86)	25 (9.92)

1 Scaled distance represents the K-factor and corresponding overpressure value in English or Metric units.

Table 2-2
BLAST OVERPRESSURE EFFECTS TO UNPROTECTED EARS

Table 2-3. Blast Overpressure Effects to Select Material and Structures (Sheet 1 of 2).

Material/Structure Description	Expected Damage from Blast Overpressure	Incident Overpressure psi (kPa)	Scaled Distance[1] K-Factor (K(m))
Unstrengthened building (wood frame structure)	Roof rafter cracked	0.5-1.5 (3.4-10.3)	77.3-33.2 (30.5-13.1)
	Studs and sheathing cracked	1-3 (6.8-20.6)	45.7-20.0 (18.1-7.9)
	Total destruction/collapse	5-8 (34.4-55.1)	14.1-11.0 (11-5-4.3)
Unstrengthened building (metal structures)	Corrugated aluminum/steel paneling moderately buckled/joints separated	0.5-1.0 (3.4-6.8)	77-45.7 (30.5-18.1)
	Severe buckling/some panels torn off	1-2 (6.8-13.7)	45.7-26.7 (18.1-10.5)
	Total destruction of siding/interior destroyed, frame failure may occur if siding has been reinforced or strengthened	≥3 (≥20.6)	≥20 (≥7.3)
Unstrengthened building (concrete block or brick walls, 8-12 inches thick)	Severe damage/shattering (unreinforced)	≥2 (≥13.7)	≥26.7 (≥10.6)
	Severe damage/shattering (reinforced)	≥3 (≥20.6)	≥20 (≥7.9)
	Total destruction/collapse	≥7 (48.26)	≥ 11.8 (≥4.68)
Reinforced concrete walls	Moderate cracking	3-4 (20.6-27.5)	20.0-16.5 (7.9-6.5)
	Severe spalling/some displacement	5-8 (34.4-55.1)	14.4-11.0 (5.7-4.3)
	Concrete shelter , bare steel remains	10-14 (68.9-96.5)	9.8-8.2 (3.8-3.2)
	Total destruction	≥14 (≥96.5)	≥8.2 (≥3.2)

1 Scaled distance represents the K-factor and corresponding overpressure value in English or Metric units.

Table 2-3:1
BLAST OVERPRESSURE EFFECTS TO SELECT MATERIAL AND STRUCTURES (SHEET 1 OF 2)

Table 2-3. Blast Overpressure Effects to Select Material and Structures (Sheet 2 of 2).

Material/Structure Description	Expected Damage from Blast Overpressure	Incident Overpressure psi (kPa)	Scaled Distance[1] K-Factor (K(m))
Unpressurized storage tanks	Slight	0.5-1.5 (3.4-10.3)	77.3-33.2 (30.6-13.1)
	Severe	3-4 (20.6-27.5)	20.0-16.5 (7.9-6.5)
	Total destruction/collapse	≥8 (≥55.1)	≥11 (≥4.3)
Steel towers	Blow down	30 (206.8)	5.8 (2.3)
Wooden utility poles	Snapping failure	5 (34.4)	14.4 (5.7)
Heavy machinery (generators, compressors, etc.)	Moderate damage	6-8 (41.3-55.1)	12.9-11.0 (5.1-4.3)
	Complete displacement	8-10 (55.1-68.9)	11.0-9.8 (4.3-3.8)
	Total destruction	≥10 (≥68.9)	≥9.8 (≥3.8)
Vehicles/trailers	Total destruction	10-14 (68.9-96.5)	9.8-8.2 (3.8-3.2)
Aircraft	Control surface or other minor damage	1-2 (6.8-13.7)	45.7-26.7 (18.1-10.5)
	Major repair	2-3 (13.7-20.6)	26.7-20.0 (10.5-7.9)
	Total destruction	≥4 (≥27.5)	≥16.5 (≥6.5)
Loaded railcars	Overturning	0.5-1 (3.4-6.8)	77.3-45.7 (30.6-18.1)

1 Scaled distance represents the K-factor and corresponding overpressure value in English or Metric units.

Table 2-3:2

BLAST OVERPRESSURE EFFECTS TO SELECT MATERIAL AND STRUCTURES (SHEET 2 OF 2)

Table 2-4. Probability of Glass Breakage and Potential Flying Glass Hazards (Sheet 1 of 2).

Scaled Distance[1] K-Factor	Scaled Distance[1] (K(m))	Estimated Incident Overpressure /Reflected Pressure psi	(kPa)	Probability (%) of Breakage for Windows Facing PES and (Expected Flying Glass Hazard Threat) Window Description[2] 1	2	3
600	(238)	0.03/0.06	(0.21/0.41)	0 (a)	0 (a)	0 (a)
500	(198)	0.04/0.08	(0.28/0.55)	0 (a)	0 (a)	0 (a)
328	(130)	0.08/0.15	(0.55/1.03)	0 (a)	0.2 (a)	1.5 (a)
180	(71)	0.18/0.35	(1.24/2.41)	0.5 (a)	4.9 (a)	34.3 (b)
150	(60)	0.23/0.45	(1.59/3.10)	1.4 (a)	13.2 (a)	69.1 (b)
100	(39.7)	0.40/0.81	(2.76/5.58)	9.7 (b)	75 (b)	100 (b)
80	(31.7)	0.55/1.12	(3.79/7.72)	22.7 (b)	99.5 (b)	100 (c)
50	(19.8)	1.01/2.07	(6.96/14.27)	71.8 (d)	100 (d)	100 (d)
40	(15.8)	1.34/2.78	(9.23/19.16)	93.9 (d)	100 (d)	100 (d)
≤ 24	(≤ 9.5)	2.66/5.70	(18.34/39.30)	100 (d)	100 (d)	100 (d)

[1] **Scaled distance represents the K-factor and corresponding overpressure value in English or Metric units.**

[2] **WINDOW DIMENSIONS ARE IN INCHES; AREA IN SQUARE FEET:**
1. 12 X 24 X 0.088 (2ft^2 Float Annealed)
2. 24 x 24 x 0.088 (4ft^2 Float Annealed)
3. 42 x 36 x 0.12 (10.5ft^2 Float Annealed)

FLYING GLASS HAZARD THREAT AND ASSOCIATED BIOLGICAL EFFECTS TO EXPOSED UNPROTECTED PERSONNEL.

(a) NO BREAK: No visible damage to glazing or frame assembly. Falling glass hazards are not expected.

(b) BREAK SAFE: Glass fragments are not expected beyond 3 feet from the window opening. Some glass fragments may be retained in frame assembly. Falling glass hazards should be expected. Injuries to unprotected personnel within 3 feet could sustain skin lacerations or penetration wounds.

(c) LOW: Glass fragments are projected 3 to approximately 10 feet from window opening, but not exceeding 2 feet above the floor beyond 3 feet from the window opening. Some glass fragments may be retained in frame assembly. Injuries to unprotected personnel within 10 feet could sustain skin lacerations and penetrations/puncture wounds from small fragments. In addition to the injuries sustained from small fragments, injuries from large fragments could include skull fractures and body wall (thorax and abdomen) penetrations. Falling glass hazards should be expected below and both within and outside of the window area.

(d) HIGH: Glass fragments are projected greater than 2 feet high and beyond 3 feet from the window opening. Injuries to unprotected personnel anywhere within a 20-degree arch to each side of the centerline axis of a window could include skin lacerations and penetration wounds, skull fractures, and body wall (thorax and abdomen) penetration/puncture wounds. Denudation is possible. There is a lesser chance of falling glass for windows directly effected.

Table 2-4:1

PROBABILITY OF GLASS BREAKAGE AND POTENTIAL FLYING GLASS HAZARDS (SHEET 1 OF 2)

Table 2-4. Probability of Glass Breakage and Potential Flying Glass Hazards (Sheet 2 of 2).

Scaled Distance[1] K-Factor	Scaled Distance[1] (K(m))	Estimated Incident Overpressure /Reflected Pressure psi	(kPa)	Probability (%) of Breakage for Windows Facing PES and Expected Flying Glass Hazard Threat — Window Description[2] 4	5	6	7
600	(238)	0.03/0.06	(0.21/0.41)	0 (a)	0.3 (a)	0.5 (a)	8 (a)
500	(198)	0.04/0.08	(0.28/0.55)	0.1 (a)	0.6 (a)	1.3 (a)	13 (a)
328	(130)	0.08/0.15	(0.55/1.03)	1.2 (a)	4.0 (a)	11.2 (a)	25 (b)
180	(71)	0.18/0.35	(1.24/2.41)	10.5 (b)	75.4 (b)	77.1 (b)	50 (b)
150	(60)	0.23/0.45	(1.59/3.10)	21.6 (b)	98.3 (b)	95.2 (b)	98 (b)
100	(39.7)	0.40/0.81	(2.76/5.58)	93.5 (c)	100 (c)	100 (c)	100 (c)
80	(31.7)	0.55/1.12	(3.79/7.72)	100 (d)	100 (d)	100 (d)	100 (d)
50	(19.8)	1.01/2.07	(6.9/14.3)	100 (d)	100 (d)	100 (d)	100 (d)
40	(15.8)	1.34/2.78	(9.2/19.2)	100 (d)	100 (d)	100 (d)	100 (d)
≤ 24	(≤ 9.5)	2.66/5.70	(18.3/39.3)	100 (d)	100 (d)	100 (d)	100 (d)

[1] **Scaled distance represents the K-factor and corresponding overpressure value in English or Metric units.**

[2] **WINDOW DIMENSIONS ARE IN INCHES; AREA IN SQUARE FEET:**

4. 60 x 42 x 0.22 (17.5ft^2 Plate Annealed)
5. 72 x 60 x 0.22 (30ft^2 Plate Annealed)
6. 120 x 60 x 0.30 (50ft^2 Plate Annealed)
7. 216 x 216 x 0.74 (323ft^2 Plate Annealed)

FLYING GLASS HAZARD THREAT AND ASSOCIATED BIOLGICAL EFFECTS TO EXPOSED UNPROTECTED PERSONNEL.

(a) NO BREAK: No visible damage to glazing or frame assembly. Falling glass hazards are not expected.

(b) BREAK SAFE: Glass fragments are not expected beyond 3 feet from the window opening. Some glass fragments may be retained in frame assembly. Falling glass hazards should be expected. Injuries to unprotected personnel within 3 feet could sustain skin lacerations or penetration wounds.

(c) LOW: Glass fragments are projected 3 to approximately 10 feet from window opening, but not exceeding 2 feet above the floor beyond 3 feet from the window opening. Some glass fragments may be retained in frame assembly. Injuries to unprotected personnel within 10 feet could sustain skin lacerations and penetrations/puncture wounds from small fragments. In addition to the injuries sustained from small fragments, injuries from large fragments could include skull fractures and body wall (thorax and abdomen) penetrations. Falling glass hazards should be expected below and both within and outside of the window area.

(d) HIGH: Glass fragments are projected greater than 2 feet high and beyond 3 feet from the window opening. Injuries to unprotected personnel anywhere within a 20-degree arch to each side of the centerline axis of a window could include skin lacerations and penetration wounds, skull fractures, and body wall (thorax and abdomen) penetration/puncture wounds. Denudation is possible. There is a lesser chance of falling glass for windows directly effected.

Table 2-4:2
PROBABILITY OF GLASS BREAKAGE AND POTENTIAL FLYING GLASS HAZARDS (SHEET 2 OF 2)

Table 3-1. TNT Equivalent Weight Ratios and Densities for Select Explosive Materials (Sheet 1 of 4).

Explosive	Composition/Atomic Formula	Average Equivalent Weight (higher of pressure or impulse)	Density lb/in³ (kg/m³)
Amatol 60/40	Ammonium nitrate-80%; TNT 20%	0.95	0.0564 (1560)
Amatol 50/50	Ammonium nitrate-50%; TNT-50%	0.97	--
Ammonium nitrate[1]	--	0.70	0.0621 (1018)
Ammonium Perchlorate	NH_4ClO_4	0.60	0.0682 (1118)
ANFO		0.83	--
Baratol		0.70	0.0942 (1544)
Baronal	AL-15%; barium nitrate-50%; TNT-35%	1.11	--
Black Powder	Potassium nitrate-74%; Sulfur-10.4%; Charcoal-15%	--	0.0697 (1142)
CH-6		1.3	0.0621 (1018)
Composition A-3	RDX-91%; Wax –9%	1.09	0.0582 (0.954)
Composition B	RDX-59.5%; TNT-39.5%; Wax-1%	1.16	0.0621 (1018)
Composition C-3	RDX-77%; Tetryl-3%; TNT-4%; DNT-10%; NC-1%	1.09	0.0578 (1600)
Composition C-4	RDX-91%;Plasticizer-9%	1.37	0.0578 (1600)
Cyclotol 75/25	RDX-75%; TNT 25%	1.26	0.0632 (1036)
Cyclotol 70/30	RDX-70%; TNT-30%	1.14	--
Cyclotol 60/40	RDX-60%; TNT-40%		--
DATP	2,4,6-Trinitro-1,3-Benzenediamine	0.9	--
Destex	TNT-74.4%; AL-19.1%; Composition D2-4.5%; Acetylene Carbon Black-1.9%; Lecithin-0.1%	1.21	--
DBX	AN-21%; RDX-21%;TNT-40%; AL-18%	1.27	--
Dynamite, Nitroglycerin (NG)	NG, Sodium Nitrate, woodpulp	0.9	--
Dynamite, Ammonia (20% strength	*	0.9	--
Dynamite, Gelatin (50% strength)	*	0.8	--
Dynamite, Gelatin (20% strength)	*	0.7	--

1 Ammonium nitrate in dry bulk not mixed with fuel oil.

Table 3-1:1

TNT EQUIVALENT WEIGHT RATIOS AND DENSITIES FOR SELECT EXPLOSIVE MATERIALS (SHEET 1 OF 4)

Table 3-1. TNT Equivalent Weight Ratios and Densities for Select Explosive Materials (Sheet 2 of 4).

Explosive	Composition/Atomic Formula	Average Equivalent Weight (higher of pressure or impulse)	Density lb/in^3 (kg/m^3)
Ednatol 55/45	Ethylenedinitramine (Haleite)-55%; TNT-45%	1.10	0.0578 (0.947)
Explosive D	Ammonium Picrate	0.85	0.0588 (0.964)
FIXNOR	Binary: 1part unknown flammable liquid; 1 part unknown powder composition	0.85	0.0325 (0.533)
H-6	RDX-45.1%; TNT-29.2%;Al-21%; Wax-4.7%	1.38	0.0636 (1042)
HBX-1	RDX-40.4%; TNT-37.8%;Al-17.1%; Wax-4.7%	1.17	0.0611 (1001)
HBX-3	RDX-31.3%; TNT-29%; AL-34.8%; Wax-4.9%	1.14	0.0661 (1083)
HMX	Cyclotetramethy lenetetranitramine	1.56	0.0682 (1118)
HNS	2,2',4,4',6,6' Hexanitrostilbene	1.3	0.0621 (1718)
LX-03	HMX-70%; DATA- 20% Viton A-10%	1.24	0.0523 (0.857)
LX-04	HMX-85%;Viton-15%	1.26	0.0676 (1094)
LX-10	HMX/Viton A	1.49	0.0682 (1118)
LX-14	HMX-95.5%;Estane-4.5%	1.85	0.0668 (1095)
LX-15	HNS-95%; Kel-F(binder)-5%	1.4	0.0632 (1036)
LX-16	PETN-96%; FPC(binder)-4%	1.5	0.0578 (0.947)
LX-17	TATB-92.5%; Kel-F(binder)-7.5%	1.2	0.0686 (1124)
Minol II	AN-40%; TNT-40%; AL-20%	1.2	0.0606 (0.993)
Nitroglycerin	$CH_2NO_3CHNO_3CH_2NO_3$	1.90	--
Nitroguanodine	$H_2NC(NH)NH\ NO_2$	0.79	--
Octol 75/25	HMX-75%; TNT-25%	1.02	0.0657 (1077)
Octol 70/30	HMX-75%; TNT-30%	1.14	0.0650 (1065)
Octol 85/15	HMX-85%; TNT-15%	1.3	0.0671 (1.100)

Table 3-1:2
TNT EQUIVALENT WEIGHT RATIOS AND DENSITIES FOR SELECT EXPLOSIVE MATERIALS (SHEET 2 OF 4)

Table 3-1. TNT Equivalent Weight Ratios and Densities for Select Explosive Materials (Sheet 3 of 4)

Explosive	Composition/Atomic Formula	Average Equivalent Weight (higher of pressure or impulse)	Density lb/in³ (kg/m³)
PBXIH-135	AMX-45%; AL-35%,, Isodecyl pelargonate-9.34%; R45HT-9.34%	1.35	0.0588 (0.963)
PBX-9501	--	1.52	--
PBX-9502	--	1.00	0.0682 (1118)
PBX-9404	--	1.44	0.0653 (1070)
PBX-9010	--	1.29	0.0650 (1065)
PBX(AF)-108	--	1.15	0.0566 (0.928)
PBXN-4	DATB-94%;Nylon-6%	0.85	0.0617 (1011)
PBXN-5	HMX-95%; VitonA-5%	--	0.0664 (1088)
PBXN-6	--	--	0.0614 (1006)
PBXN-9	HMX-92%; Platicizer/binder-8%	1.30	0.0625 (1024)
PBXN-103	Ammonium Perchlorate-40%; Al-27%;Metroil Trinitrate (MTN)-23%; Plasticizer/binder-10%	1.31	0.0682 (1117)
PBXN-105	Ammonium Perchlorate-49.8%; Al-25.8%; RDX-7%; Plasticizer/binder-17.4%	1.35	0.0686 (1124)
PBXN-106		1.10	--
PBXN-109	RDX-64%; Al-20%; Plasticizer/binder-16%	1.43	0.0610 (1000)
PBXN-110	HMX-88%; Plasticizer/binder-12%	1.44	0.0606 (0.993)
PBXN-111	Ammonium Perchlorate-43%; Al-25%; RDX-20%; Plasticizer/binder-12%	1.39	0.0647 (1060)
PBXW-11	HMX-96%; Hytemp (binder)-3%; Plasticizer-1%	--	0.0656 (1075)
Pentolite 50/50, cast	PETN-50%; TNT-50%	1.28	0.0603 (0.988)
PETN	Pentaerythritol Tesranitrate	1.27	0.0636 (1042)
Picratol 52/48	Explosive D- 52%; TNT-48%	0.93	0.0589 (1630)

Table 3-1:3
TNT EQUIVALENT WEIGHT RATIOS AND DENSITIES FOR SELECT EXPLOSIVE MATERIALS (SHEET 3 OF 4)

Table 3-1. TNT Equivalent Weight Ratios and Densities for Select Explosive Materials (Sheet 4 of 4)

Explosive	Composition/Atomic Structure	Average Equivalent Weight (higher of pressure or impulse)	Density lb/in^3 (kg/m^3)
Picric Acid	2,4,6,-Trinitrophenol	0.93	0.0636 (1760)
RDX	Cyclotrimethylenetrinitramine	1.46	0.0650 (1065)
SEMTEX	RDX-57%; PETN-85%; hydrocarbon oil-11.6%; styrene-butadiene rubber-2.9%	1.35	0.0994 (1629)
SEMTEX A	RDX-45%; PETN-45%; binder- 8%; styrene-butadiene rubber-2.9%	1.35	0.0994 (1629)
SEMTEX 1A	PETN-83.5%; Hydrocarbon oil-12.4%; styrene-butadiene-4.1%	1.35	0.0854 (1399)
SEMTEX 1AP	PETN-83.5%; Hydrocarbon oil-12.4%; styrene-butadiene-4.1%	1.35	0.0854 (1399)
SEMTEX 2P		1.35	0.1282 (2100)
SEMTEX 2AP		1.35	0.0854 (1399)
SEMTEX 2PN		1.35	0.1282 (2100)
SEMTEX S 25	PETN powder- based	1.35	0.0610 (1000)
SEMTEX S 30	PETN powder based	1.35	0.0610 (1000)
SEMTEX S 35	PETN powder based	1.35	0.0610 (1000)
SEMTEX H	RDX-65.6%; PETN-20%; hydrocarbon oil-11.6%; styrene-butadiene rubber-2.9%	1.35	--
SEMTEX 10	PETN-85%; Acrylonitrile-butadiene rubber-3.7%; Unknown- 11.3%	1.35	0.0854 (1399)
Tetryl	2,4,6,-Trinitrophenyl-ethylnitromine	1.07	0.0618 (1013)
Tetrytol 75/25	Tetryl-75%; TNT-25%	1.06	0.0578 (0.947)
TNETB	2,2,2, Trintroethul or 4,4,4, Tirnitrobutzate $C_6H_6N_6O_{14}$	1.36	--
TNT	2,4,6,-Trinitrotoluene	1.00	0.0592 (0.970)
Torpex	RDX-42%; TNT-40%; Al-18%	1.28	0.0650 (1065)
Tritonal 80/20	TNT-80%; Al-20%	1.07	0.0625 (1729)

Table 3-1:4
TNT EQUIVALENT WEIGHT RATIOS AND DENSITIES FOR SELECT EXPLOSIVE MATERIALS (SHEET 4 OF 4)

Table 3-10. Quantity Distance Ranges for Select Energetic Liquids/Propellants.

Energetic Liquid	Density lb/gal (kg/l)	Minimal QDR to Apply Feet or K-factor (Meters or K(m))
Ethylene Oxide	7.4	800[3] or 300ft[4] or greater of K50[1,2] or HFDR[1,2]
	(0.89)	(244 or 91)or greater of (K(m)19.84) or HFDR
Hydrazine, > 64%	8.4	800[3] or 300ft[4]
	(1.01)	(244 or 91 m)
Hydrogen, liquid	0.59	600ft[5] or greater of K50[1,2] or HFDR[1,2]
	(0.07)	(183) or greater of (K(m)19.84) or HFDR
Hydrogen Peroxide, > 60%	11.6	800ft[3] or greater of K-50[1,2] or HFDR[1,2]
	(1.39)	(244) (K(m)19.84) or HFDR
Hydroxylammonium nitrate (HAN)	(25 – 95% wt.) 11.9 –13.4	800ft[3] or greater of K50[1,2] or HFDR[1,2]
	(1.43-1.61)	(244) (K(m)19.84) or HFDR
Inhibited Red Fuming Nitric acid (IRFNA)	12.9	75[7], 200[8], 510ft[5] or greater of K50[1,2] or HFDR[1,2]
	(1.55)	(23, 61, 155) or greater of (K(m)19.84) or HFDR
JP-10	7.8	75[7], 200[8], 510ft[5] or greater of K50[1,2] or HFDR[1,2]
	(0.93)	(23, 61, 155) or greater of (K(m)19.84) or HFDR
Methylhydrazine	7.9	800[3] or 300ft[4] or greater of K50[1,2] or HFDR[1,2]
	(3.6)	(244 or 91) or greater of (K(m)19.84) or HFDR
Nitromethane	9.5	Greater of K50[1,2] or HFDR[1,2]
	(1.14)	(K(m)19.84) or HFDR
Otto Fuel II	10.3	800[3] or 300ft[4] or greater of K50[1,2] or HFDR[1,2]
	(1.23)	(244 or 91) or greater of (K(m)19.84) or HFDR
Propylene Oxide	7.2	800[3] or 300ft[4] or greater of K50[1,2] or HFDR[1,2]
	(0.86)	(244 or 91) or greater of (K(m)19.84) or HFDR
UDMH/hydrazine	7.5	75[7], 200[8], 510ft[5] or greater of K50[1,2] or HFDR[1,2]
	(0.90)	(23, 61, 155) or greater of (K(m)19.84) or HFDR

1 Use TNT equivalent ratio not less than 1.
2 Material stored in bulk storage or transport containers with a reasonable risk of vapor cloud explosion; includes overpressure and fragment producing effects and/or interaction with oxidizers.
3 Material stored in small (non-bulk) shipping containers, containers used in small aerospace vehicles, or similar vessels that provide heavy confinement, (burst pressure >100 psi (690 kPa).
4 Material stored in small (non-bulk) shipping containers, containers used in small aerospace vehicles, or similar vessels that provide relatively heavy confinement, (burst pressure ≤ 100 psi (690 kPa).
5 Quantities ≤ 10,000 lbs (4,536 kg).
6 Quantities > 10,000 lbs. (4,536 kg).
7 Quantities ≤ 50 lbs. (23 kg) when located or used in close proximity with oxidizers.
8 Quantities ≥ 50 lbs (23 kg) but ≤ 200 lbs (91 kg) when located or used in close proximity with oxidizers.

Table 3-10
QUALITY DISTANCE RANGES FOR SELECT ENERGETIC LIQUIDS/PROPELLANTS

Table 3-11. TNT Equivalent Ratios for Select Flammable Gas-Air Mixtures.

Gas	Flammability/ Detonation Range in Percentages	Combustion TNT Equivalent Ratio	Detonation TNT Equivalent Ratio
n-Butane	1.90-8.50	3.02	10.12
Propane	2.20-9.50	3.06	10.26
Ethane	3.00-12.50	3.14	10.51
Methane	5.00-15.00	3.30	11.07
Ethylene Oxide	3.00-80.00	1.76	5.91

Table 3-11
TNT EQUIVALENT RATIOS FOR SELECT FLAMMABLE GAS-AIR MIXTURES

Table 3-12. Minimal Material Thickness to Prevent Primary Fragment Perforation (Material Located at the HFDR)[1]

Description	4000 psi concrete (thickness to prevent spalling) Inches (Millimeters)	Mild Steel Inches (Millimeters)	Aluminum Inches (Millimeters)	Plexiglass Inches (Millimeters)	Bullet Resistant Glass Inches (Millimeters)	Sandy Soil Inches (Millimeters)
Projectiles and Bombs:						
≤ 81-mm	4 (102)	0.7 (18)	1.5 (38)	4.01 (102)	3 (76)	17.3 (439)
> 81-mm ≤ 8-inch	10 (254)	1.8 (46)	3.4 (86)	7.01 (178)	4.59 (117)	36.39 (924)
> 8-inch ≤ 18-inches	18 (457)	3.13 (80)	6.03 (153)	10.7 (272)	10.19 (259)	61.4 (1,560)
Miscellaneous						
M16A1 Landmine, APERS	4.85 (123)	0.89 (23)	1.87 (47)	3.66 (93)	2.97 (75)	17.13 (435)
M21, Landmine, AT	5.20 (132)	0.79 (20)	1.74 (44)	2.37 (60)	2.25 (57)	12.36 (314)
M39, Grenade, APERS	0.31 (8)	0.05 (1)	0.11 (3)	0.37 (9)	0.24 (6)	1.3 (33)

1 Does not include shaped charge borne projectile perforation.

Table 3-12

MINIMAL MATERIAL THICKNESS TO PREVENT PRIMARY FRAGMENT PROFORATION (MATERIAL LOCATED AT THE

Table 3-13. Sandbag Requirements for Explosion Effects Mitigation Technique.

Munition Description (cylindrical items unless noted)	Required Minimal Wall and Roof Sandbag Thickness Inches (Millimeters)	Expected Sandbag Throw Distance Inches (Millimeters)	Estimated Blast Overpressure at 80 feet (24 meters)[1] Psi (kPa)
≤30-mm	12 (305)	30 (9)	.03 (0.21)
>30-mm ≤ 90-mm	24 (610)	125 (38)	.08 (0.55)
>90-mm ≤155-mm	36 (914)	220 (67)	.09 (0.62)
Miscellaneous			
M1A1 AT landmine	24 (610)	125 (38)	.09[2] (0.62)
M21 AT landmine	36 (914)	220 (67)	.09[2] (0.62)
M16A1, APERS landmine	24 (7)	135 (41)	.08[2] (0.55)

1 Estimated high that includes an approximate 3.5-ounce (100-gram) Composition C-4 demolition charge.
2 Estimated based on explosive weight in relation to Sandbag thickness.

Table 3-13
SANDBAG REQUIREMENTS FOR EXPLOSION EFFECTS MITIGATION TECHNIQUE

Table 3-2. Cube Roots of Explosive Weights (Sheet 1 of 2).

Range of Total Explosive Weight of TNT or Equivalent					
Pounds (Kilograms)		Upper Limit Cube Root[1]	Pounds (Kilograms)		Upper Limit Cube Root[1]
>	≤		>	≤	
0.0 (0.0)	1.0 (0.45)	1.00	1,500.0 (680.4)	2,000.0 (907.2)	12.59
1.0 (0.45)	2.0 (0.91)	1.26	2,000.0 (907.2)	3,000.0 (1,363.6)	14.42
2.0 (0.91)	5.0 (2.3)	1.71	3,000.0 (1,363.6)	4,000.0 (1,818.2)	15.87
5.0 (2.3)	10.0 (4.5)	2.15	4,000.0 (1,814.4)	5,000.0 (2,268.0)	17.09
10.0 (4.5)	20.0 (9.1)	2.71	5,000.0 (2,268.0)	6,000.0 (2,721.6)	18.17
20.0 (9.1)	30.0 (13.6)	3.11	6,000.0 (2,721.6)	7,000.0 (3,175.2)	19.13
30.0 (13.6)	40.0 (18.1)	3.42	7,000.0 (3,175.2)	8,000.0 (3,628.8)	20.00
40.0 (18.1)	50.0 (22.7)	3.68	8,000.0 (3,628.8)	9,000.0 (4,082.4)	20.80
50.0 (22.7)	100.0 (45.4)	4.64	9,000.0 (4,082.4)	10,000.0 (4,536)	21.54
100.0 (45.5)	200.0 (90.0)	5.85	10,000.0 (4,536)	15,000.0 (6,804)	24.66
200.0 (90.7)	300.0 (136.1)	6.69	15,000.0 (6,804)	20,000.0 (9,072)	27.14
300.0 (136.1)	400.0 (181.4)	7.37	20,000.0 (9,072)	25,000.0 (11,340)	2924
400.0 (181.4)	500.0 (226.8)	7.94	25,000.0 (11,340)	30,000.0 (13,608)	31.07
500.0 (226.8)	600.0 (272.7)	8.43	30,000.0 (13,608)	35,000.0 (15,876)	32.71
600.0 (272.7)	700.0 (317.5)	8.88	35,000.0 (15,876)	40,000.0 (18,144)	31.19
700.0 (317.5)	800.0 (362.8)	9.28	40,000.0 (18,144)	45,000.0 (20,412)	35.56
800.0 (362.8)	900.0 (408.2)	9.65	45,000.0 (20,412)	50,000.0 (22,680)	36.84
900.0 (408.2)	1,000.0 (453.6)	10.0	50,000.0 (22,680)	55,000.0 (24,948)	38.02
1,000.0 (453.6)	1,500.0 (680.4)	11.45	55,000.0 (24,948)	60,000.0 (27,216)	39.14

[1] The upper limit cube root is based on the highest number in pounds for a given weight range.

Table 3-2:1

CUBE ROOTS OF EXPLOSIVE WEIGHTS (SHEET 1 OF 2)

Table 3-2. Cube Roots of Explosive Weights (Sheet 2 of 2).

Range of Total Explosive Weight of TNT or Equivalent					
Pounds (Kilograms)		Upper Limit Cube Root[1]	Pounds (Kilograms)		Upper Limit Cube Root[1]
>	≤		>	≤	
60,000.0 (27,216)	65,000.0 (29,484)	39.14	200,000.0 (90,720)	225,000.0 (102,060)	60.82
65,000.0 (29,484)	70,000.0 (31,752)	41.21	225,000.0 (102,060)	250,000.0 (113,400)	62.99
70,000.0 (31,752)	75,000.0 (34,020)	42.17	250,000.0 (113,400)	275,000.0 (124,740)	65.02
75,000.0 (34,020)	80,000.0 (36,288)	43.08	275,000.0 (124,740)	300,000.0 (136,080)	66.94
80,000.0 (36,288)	85,000.0 (38,556)	43.96	300,000.0 (136,080)	325,000.0 (147,420)	68.75
85,000.0 (38,556)	90,000.0 (40,824)	44.81	325,000.0 (147,420)	375,000.0 (170,100)	72.11
90,000.0 (40,824)	100,000.0 (45,360)	46.41	375,000.0 (170,100)	400,000.0 (181,440)	73.68
100,000.0 (45,360)	125,000.0 (56,700)	50.00	400,000.0 (181,440)	425,000.0 (192,780)	75.18
125,000.0 (56,700)	150,000.0 (68,040)	53.13	425,000.0 (192,780)	450,000.0 (204,120)	76.63
150,000.0 (68,040)	175,000.0 (79,380)	55.93	450,000.0 (204,120)	475,000.0 (215,460)	78.02
175,000.0 (79,380)	200,000.0 (90,720)	58.48	475,000.0 (215,460)	500,000.0 (226,800)	79.37

[1] The upper limit cube root is based on the highest number in pounds for a given weight range.

Table 3-2:2

CUBE ROOTS OF EXPLOSIVE WEIGHTS (SHEET 2 OF 2)

Table 3-3. HFDR and MFDR Determined by the Diameter of a Single Item (Sheet 1 of 4).

Diameter Inches (Millimeters)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)	Blast Overpressure Distance Range (BODR)[3] Feet (Meters)	
		[1] $142.2 \times D^{0.68}$	[1] $845.8 \times D^{0.682}$	K328	K50
>	≤	[2] $(4.81 \times D^{0.68})$	[2] $(28.70 \times D^{0.682})$	K(m)130.1	(K(m)15.87)
0.0	0.5	89	533	21	3
(0.0)	(12.7)	(27)	(163)	(6)	(0.9)
0.5	1.0	142	855	168	25
(12.7)	(25.4)	(43)	(261)	(51)	(8)
1.0	1.5	187	1,127	388	58
(25.4)	(38.1)	(57)	(344)	(118)	(18)
1.5	2.0	228	1,371	618	94
(38.1)	(50.8)	(70)	(418)	(188)	(29)
2.0	2.5	265	1,597	837	128
(50.8)	(63.5)	(81)	(487)	(255)	(39)
2.5	3.0	300	1,808	1,039	158
(63.5)	(76.2)	(91)	(551)	(316)	(48)
3.0	3.5	333	2,009	1,222	186
(76.2)	(88.9)	(102)	(612)	(372)	(57)
3.5	4.0	365	2,200	1,388	211
(88.9)	(101.6)	(111)	(671)	(423)	(64)
4.0	4.5	395	2,384	1,539	234
(101.6)	(114.3)	(120)	(727)	(469)	(71)
4.5	5.0	425	2,562	1,676	255
(114.3)	(127.0)	(130)	(781)	(511)	(69)
5.0	5.5	453	2,734	1,801	274
(127.0)	(139.7)	(138)	(833)	(549)	(84)
5.5	6.0	481	2,901	1,916	292
(139.7)	(152.4)	(147)	(884)	(584)	(89)
6.0	6.5	508	3,064	2,022	308
(152.4)	(165.1)	(155)	(934)	(616)	(94)
6.5	7.0	534	3,223	2,119	323
(165.1)	(177.8)	(163)	(982)	(646)	(98)
7.0	7.5	560	3,378	2,210	337
(177.8)	(190.5)	(171)	(1,030)	(674)	(103)
7.5	8.0	585	3,530	2,294	350
(190.5)	(203.2)	(178)	(1,076)	(699)	(107)
8.0	8.5	609	3,679	2,372	362
(203.2)	(215.9)	(186)	(1,121)	(723)	(110)

1 Equation in English Units.
2 Equation in Metric Units.
3 Derived from the Relationship Between the Upper Bound Explosive Weight and Diameter up to 18 inches (457 millimeters).

Table 3-3:1

HFDR AND MFDR DETERMINED BY THE DIAMETER OF A SINGLE ITEM (SHEET 1 OF 4)

Table 3-3. HFDR and MFDR Determined by the Diameter of a Single Item (Sheet 2 of 4).

Diameter		Hazardous Fragmentation Distance Range (HFDR)	Maximum Fragmentation Distance Range (MFDR)	Blast Overpressure Distance Range (BODR)[3]	
Inches (Millimeters)		Feet (Meters)	Feet (Meters)	Feet (Meters)	
		[1] $142.2 \times D^{0.68}$	[1] $845.8 \times D^{0.682}$	K328	K50
>	≤	[2] $(4.81 \times D^{0.68})$	[2] $(28.70 \times D^{0.682})$	K(m)130.1	(K(m)19.84)
8.5	9.0	634	3,825	2,445	373
(203)	(229)	(193)	(1,166)	(745)	(114)
9.0	9.5	657	3,969	2,514	382
(229)	(241)	(200)	(1,210)	(766)	(116)
9.5	10.0	681	4,110	2,579	393
(241)	(254)	(208)	(1,253)	(786)	(120)
10.0	10.5	704	4,249	2,639	402
(254)	(267)	(215)	(1,295)	(804)	(123)
10.5	11.0	726	4,386	2,697	411
(267)	(279)	(221)	(1,337)	(822)	(125)
11.0	11.5	748	4,521	2,751	419
(279)	(292)	(228)	(1,378)	(839)	(128)
11.5	12.0	770	4,654	2,802	427
(292)	(305)	(235)	(1,419)	(854)	(130)
12.0	12.5	792	4,786	2,851	435
(305)	(318)	(241)	(1,459)	(869)	(133)
12.5	13.0	814	4,916	2,897	442
(318)	(330)	(248)	(1,498)	(833)	(135)
13.0	13.5	835	5,044	2,941	448
(330)	(343)	(255)	(1,537)	(896)	(137)
13.5	14.0	856	5,170	2,983	455
(343)	(356)	(261)	(1,576)	(909)	(139)
14.0	14.5	876	5,296	3,024	461
(356)	(368)	(267)	(1,614)	(922)	(141)
14.5	15.0	897	5,419	3,062	467
(368)	(381)	(273)	(1,652)	(933)	(142)
15.0	15.5	917	5,542	3,099	472
(381)	(394)	(280)	(1,689)	(945)	(144)
15.5	16.0	937	5,663	3,134	478
(394)	(406)	(286)	(1,726)	(955)	(146)
16.0	16.5	957	5,783	3,168	483
(406)	(419)	(292)	(1,763)	(966)	(147)
16.5	17.0	976	5,902	3,200	488
(419)	(432)	(297)	(1,799)	(975)	(149)
17.0	17.5	996	6,020	3,231	493
(432)	(445)	(306)	(1,835)	(985)	(150)
17.5	18.0	1,015	6,137	3,261	497
(445)	(457)	(309)	(1,871)	(994)	(151)

1 Equation in English Units.
2 Equation in Metric Units.
3 Derived on the Relationship Between the Upper Bound Explosive Weight and Diameter up to 18 inches (457 millimeters).

Table 3-3:2
HFDR AND MFDR DETERMINED BY THE DIAMETER OF A SINGLE ITEM (SHEET 2 OF 4)

Table 3-3. HFDR and MFDR Determined by the Diameter of a Single Item (Sheet 3 of 4).

Diameter Inches (Millimeters)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)
		[1] $142.2*D^{0.68}$	[1] $845.8*D^{0.682}$
>	≤	[2] $(4.81*D^{0.68})$	[2] $(28.70*D^{0.682})$
18.5	19.0	1,053	6,368
(470)	(483)	(321)	(1,941)
19.0	19.5	1,072	6,481
(483)	(495)	(327)	(1,975)
19.5	20	1,072	6,481
(495)	(508)	(327)	(1,975)
20.0	20.5	1,109	6,706
(508)	(521)	(338)	(2,044)
20.5	21.0	1,127	6,746
(521)	(533)	(344)	(2,056)
21.0	22.0	1,163	7,037
(533)	(559)	(354)	(2,145)
22.0	23.0	1,199	7,254
(559)	(584)	(341)	(2,211)
23.0	24.0	1,234	7,467
(584)	(610)	(376)	(2,276)
24.0	25.0	1,269	7,678
(610)	(635)	(387)	(2,340)
25.0	26.0	1,303	7,886
(635)	(660)	(397)	(2,404)
26.0	27.0	1,337	8,092
(660)	(686)	(408)	(2,466)
27.0	28.0	1,371	8,295
(686)	(711)	(418)	(2,528)
28.0	29.0	1,404	8,496
(711)	(737)	(428)	(2,590)
29.0	30.0	1,437	8,695
(737)	(762)	(438)	(2,650)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-3:3
HFDR AND MFDR DETERMINED BY THE DIAMETER OF A SINGLE ITEM (SHEET 3 OF 4)

Table 3-3. HFDR and MFDR Determined by the Diameter of a Single Item (Sheet 4 of 4).

Diameter Inches (Millimeters) >	Diameter Inches (Millimeters) ≤	Hazardous Fragmentation Distance Range (HFDR) Feet (Meters) [1] $142.2 \times D^{0.68}$ [2] $(4.81 \times D^{0.68})$	Maximum Fragmentation Distance Range (MFDR) Feet (Meters) [1] $845.8 \times D^{0.682}$ [2] $(28.70 \times D^{0.682})$
30	31	1,469	8,891
(762)	(787)	(448)	(2,710)
31	32	1,501	9,086
(787)	(813)	(458)	(2,769)
32	33	1,533	9,279
(813)	(838)	(467)	(2,828)
33	34	1,564	9,470
(838)	(864)	(477)	(2,886)
34	35	1,595	9,659
(864)	(889)	(486)	(2,944)
35	36	1,626	9,846
(889)	(914)	(496)	(3,001)
36	37	1,657	10,032
(914)	(940)	(505)	(3,058)
37	38	1,687	10,216
(940)	(956)	(514)	(3,114)
38	39	1,717	10,398
(956)	(991)	(523)	(3,169)
39	40	1,747	10,580
(991)	(1,016)	(532)	(3,225)
40	45	1,893	11,465
(1,016)	(1,143)	(576)	(3,495)
45	50	2,033	12,319
(1,143)	(1,270)	(620)	(3,755)
50	55	2,169	13,146
(1,270)	(1,397)	(661)	(4,007)
55	60	2,302	13,950
(1,397)	(1,524)	(702)	(4,252)
60	65	2,430	14,732
(1,524)	(1,651)	(741)	(4,490)
65	70	2,556	15,496
(1,651)	(1,270)	(779)	(4,723)
70	75	2,679	16,243
(1,778)	(1,905)	(817)	(4,951)
75	80	2,799	16,974
(1,905)	(2,032)	(853)	(5,174)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-3:4
HFDR AND MFDR DETERMINED BY THE DIAMETER OF A SINGLE ITEM (SHEET 4 OF 4)

Table 3-4. HFDR and MFDR Determined by the Net Explosive Weight of a Single Item (Sheet 1 of 4).

NEWQD Pounds (Kilograms)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)	Blast Overpressure Distance Range (BODR) Feet (Meters)	
		[1] $315.9 \times W^{0.164}$	[1] $2756 + 565.9 \times \ln(W)$	K328	K50
>	≤	[2] $(109.62 \times Q^{0.164})$	[2] $(976.4 + 172.5 \times \ln(Q))$	K(m)130.1	(K(m)19.84)
0.0	0.10	217	1,453	152	23
(0.0)	(0.05)	(66)	(443)	(46)	(7)
0.10	0.20	243	1,845	192	29
(0.05)	(0.09)	(74)	(562)	(59)	(9)
0.20	0.30	266	2,075	220	33
(0.09)	(0.14)	(81)	(632)	(67)	(10)
0.30	0.40	272	2,237	242	37
(0.14)	(0.18)	(83)	(682)	(74)	(11)
0.40	0.50	282	2,364	260	40
(0.18)	(0.23)	(86)	(721)	(79)	(12)
0.50	0.60	291	2,467	277	42
(0.23)	(0.27)	(89)	(752)	(84)	(13)
0.60	0.70	298	2,554	291	44
(0.27)	(0.32)	(91)	(778)	(88.6)	(13)
0.70	0.80	305	2,630	304	46
(0.32)	(0.36)	(93)	(802)	(93)	(14)
0.80	0.90	310	2,696	317	48
(0.36)	(0.41)	(94)	(821)	(97)	(15)
0.90	1.0	316	2,756	328	50
(0.41)	(0.45)	(96)	(1,250)	(100)	(15)
1.0	2.0	354	3,148	413	63
(0.45)	(0.91)	(109)	(960)	(126)	(19)
2.0	3.0	378	3,378	473	72
(0.91)	(1.4)	(115)	(1,030)	(144)	(22)
3.0	4.0	397	3,540	521	79
(1.36)	(1.8)	(121)	(1,079)	(159)	(24)
4.0	5.0	411	3,667	561	85
(1.8)	(2.3)	(125)	(1,118)	(171)	(26)
5.0	6.0	424	3,770	596	91
(2.3)	(2.7)	(129)	(1,149)	(182)	(28)
6.0	7.0	435	3,857	627	96
(2.7)	(3.2)	(133)	(1,176)	(191)	(29)
7.0	8.0	444	3,942	656	100
(3.2)	(3.6)	(135)	(1,202)	(200)	(30)
8.0	9.0	453	3,999	682	104
(3.6)	(4.1)	(138)	(1,219)	(208)	(32)
9.0	10.0	461	4,059	707	108
(4.1)	(4.5)	(141)	(1,237)	(215)	(33)
10.0	15.0	493	4,451	809	123
(4.5	(6.8)	(150)	(1,357)	(247)	(37)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-4:1
HFDR AND MFDR DETERMINED BY THE NET EXPLOSIVE WEIGHT OF A SINGLE ITEM (SHEET 1 OF 4)

Table 3-4. HFDR and MFDR Determined by the Net Explosive Weight of a Single Item (Sheet 2 of 4).

NEWQD Pounds (Kilograms)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)	Blast Overpressure Distance Range (BODR) Feet (Meters)	
		[1] 315.9 x $W^{0.164}$	[1] 2756 + 565.9 x ln(W)	K328	K50
>	≤	[2] (109.62 x $Q^{0.164}$)	[2] (976.4 + 172.5 x ln(Q))	K(m)130.1	(K(m)19.84)
15.0	20.0	516	4,451	890	136
(6.8)	(9.1)	(157)	(1,357)	(271)	(41)
20.0	25.0	536	4,578	959	146
(9.1)	(11.3)	(163)	(1,395)	(292)	(45)
25.0	30.0	552	4,681	1,019	155
(11.3)	(13.6)	(168)	(1,427)	(311)	(47)
30.0	35.0	566	4,768	1,073	164
(13.6)	(15.9)	(173)	(1,453)	(327)	(50)
35.0	40.0	578	4,843	1,122	171
(15.9)	(18.1)	(176)	(1,476)	(342)	(52)
40.0	45.0	590	4,910	1,167	178
(18.1)	(20.4)	(180)	(1,497)	(356)	(54)
45.0	50.0	600	4,970	1,208	184
(20.4)	(22.7)	(183)	(1,515)	(368)	(56)
50.0	55.0	609	5,024	1,247	190
(22.7)	(24.9)	(186)	(1,531)	(380)	(58)
55.0	60.0	626	5,073	1,284	196
(24.9)	(27.2)	(191)	(1,546)	(391)	(60)
60.0	65.0	626	5,118	1,319	201
(27.2)	(29.5)	(191)	(1,560)	(402)	(61)
65.0	70.0	634	5,160	1,352	206
(29.5)	(31.8)	(193)	(1,573)	(412)	(63)
70.0	75.0	641	5,199	1,383	211
(31.8)	(34.0)	(195)	(1,585)	(422)	(64)
75.0	80.0	648	5,235	1,413	215
(34.0)	(36.3)	(198)	(1,596)	(431)	(66)
80.0	85.0	655	5,270	1,442	220
(36.3)	(38.6)	(200)	(1,606)	(440)	(67)
85.0	90.0	661	5,302	1,470	224
(38.6)	(40.8)	(201)	(1,616)	(448)	(68)
90.0	95.0	667	5,333	1,497	228
(40.8)	(43.1)	(203)	(1,625)	(456)	(69)
95.0	100	672	5,362	1,522	232
(43.1)	(45.4)	(205)	(1,634)	(464)	(71)
100	200	753	5,754	1,918	292
(45.4)	(90.7)	(230)	(1,754)	(585)	(89)
200	300	805	5,984	2,196	335
(91)	(136)	(245)	(1,824)	(669)	(102)
300	400	844	6,146	2,417	368
(136)	(181)	(257)	(1,873)	(737)	(112)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-4:2
HFDR AND MFDR DETERMINED BY THE NET EXPLOSIVE WEIGHT OF A SINGLE ITEM (SHEET 2 OF 4)

Table 3-4. HFDR and MFDR Determined by the Net Explosive Weight of a Single Item (Sheet 3 of 4).

NEWQD Pounds (Kilograms)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)	Blast Overpressure Distance Range (BODR) Feet (Meters)	
		[1] $315.9 \times W^{0.164}$	[1] $2756 + 565.9 \times \ln(W)$	K328	K50
>	≤	[2] $(109.62 \times Q^{0.164})$	[2] $(976.4 + 172.5 \times \ln(Q))$	K(m)130.1	(K(m)19.84)
400	500	875	6,273	2,603	397
(181)	(227)	(267)	(1,912)	(793)	(121)
500	600	902	6,376	2,766	422
(227)	(272)	(275)	(1,943)	(843)	(129)
600	700	925	6,463	2,912	444
(272)	318	(282)	(1,970)	(888)	(135)
700	800	945	6,539	3,045	464
(272)	(363)	(288)	(1,993)	(928)	(141)
800	1,000	981	6,665	3,280	500
(227)	(454)	(299)	(2,031)	(1,000)	(152)
1,000	2,000	1,099	7,057	4,133	630
(454)	(907)	(335)	(2,151)	(1,260)	(192)
2,000	3,000	1,174	7,287	4,731	721
(907)	(1,361)	(358)	(2,221)	(1,442)	(220)
3,000	4,000	1,231	7,449	5,207	794
(1,361)	(1,814)	(375)	(2,270)	(1,578)	(242)
4,000	5,000	1,277	7,576	5,609	855
(1,814)	(2,268)	(389)	(2,309)	(1,710)	(261)
5,000	6,000	1,316	7,679	5,960	909
(2,268)	(2,722)	(401)	(2,341)	(1,817)	(277)
6,000	7,000	1,349	7,766	6,274	956
(2,722)	(3,175)	(411)	(2,367)	(1,912)	(291)
7,000	8,000	1,379	7,842	6,560	1,000
(3,175)	(3,629)	(420)	(2,390)	(1,999)	(305)
8,000	9,000	1,406	7,908	6,823	1,040
(3,629)	(4,082)	(429)	(2,410)	(2,080)	(317)
9,000	10,000	1,431	7,968	7,067	1,077
(4,082)	(4,536)	(436)	(2,429)	(2,154)	(328)
10,000	20,000	1,603	8,360	8,903	1,357
(4,536)	(9,072)	(489)	(2,548)	(2,714)	(414)
20,000	30,000	1,713	8,590	10,192	1,554
(9,072)	(13,608)	(522)	(2,618)	(3,107)	(474)
30,000	40,000	1,796	8,752	11,217	1,710
(13,608)	(18,144)	(547)	(2,668)	(3,419)	(521)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-4:3
HFDR AND MFDR DETERMINED BY THE NET EXPLOSIVE WEIGHT OF A SINGLE ITEM (SHEET 3 OF 4)

Table 3-4. HFDR and MFDR Determined by the Net Explosive Weight of a Single Item (Sheet 4 of 4).

NEWQD Pounds (Kilograms)		Hazardous Fragmentation Distance Range (HFDR) Feet (Meters)	Maximum Fragmentation Distance Range (MFDR) Feet (Meters)	Blast Overpressure Distance Range (BODR) Feet (Meters)	
		[1] $315.9 \times W^{0.164}$	[1] $2756 + 565.9 \times \ln(W)$	K328	K50
>	≤	[2] $(109.62 \times Q^{0.164})$	[2] $(976.4 + 172.5 \times \ln(Q))$	K(m)130.1	(K(m)19.84)
40,000	50,000	1,863	8,879	12,084	1,842
(18,144)	(22,680)	(568)	(2,706)	(3,683)	(561)
50,000	60,000	1,919	8,982	12,841	1,957
(22,680)	(27,216)	(585)	(2,738)	(3,914)	(596)
60,000	70,000	1,969	9,069	13,518	2,061
(27,216)	(31,752)	(600)	(2,764)	(4,120)	(628)
70,000	80,000	2,012	9,145	14,133	2,154
(31,752)	(36,288)	(613)	(2,787)	(4,308)	(657)
80,000	90,000	2,051	9,211	14,699	2,241
(36,288)	(40,824)	(625)	(2,808)	(4,480)	(683)
90,000	100,000	2,087	9,271	15,224	2,321
(40,824)	(45,360)	(636)	(2,826)	(4,640)	(707)
100,000	150,000	2,231	9,500	17,428	2,657
(45,360)	(68,040)	(680)	(2,896)	(5,312)	(810)
150,000	200,000	2,338	9,663	19,182	2,924
(68,040)	(90,720)	(713)	(2,945)	(5,847)	(891)
200,000	250,000	2,426	9,790	20,663	3,150
(90,720)	(113,400)	(739)	(2,984)	(6,298)	(960)
250,000	300,000	2,499	9,893	21,957	3,347
(113,400)	(136,080)	(762)	(3,015)	(6,692)	(1,020)
300,000	350,000	2,563	9,980	23,115	3,524
(136,080)	(158,760)	(781)	(3,042)	(7,045)	(1,074)
350,000	400,000	2,620	10,056	24,167	3,694
(158,760)	(181,440)	(799)	(3,065)	(7,366)	(1,133)
400,000	450,000	2,671	10,122	25,135	3,832
(181,440)	(204,120)	(814)	(3,085)	(7,661)	(1,168)
450,000	500,000	2,718	10,182	26,033	3,969
(204,120)	(226,800)	(828)	(3,103)	(7,935)	(1,210)

1 Equation in English Units.
2 Equation in Metric Units.

Table 3-4:4
HFDR AND MFDR DETERMINED BY THE NET EXPLOSIVE WEIGHT OF A SINGLE ITEM (SHEET 4 OF 4)

Table 3-5. Emergency Withdrawal Distances for Nonessential Personnel.

Hazard Division	Unknown Quantity feet (meters)	Known Quantity feet[2] (meters)
Unknown: located in facility, truck or tractor trailer	4,000 (1,219)	4,000 (1,219)
Unknown: located in railcar	5,000 (1,524)	5,000 (1,524)
1.1[1] and 1.5	**Same as unknown facility, truck, tractor trailer, or railcar as applicable**	**Transportation:** NEWQD ≤ 500 pounds QDR = 2,500 feet NEWQD ≤ 226.8 kilograms QDR = 762 meters NEWQD > 500 pounds Railcars: QDR = 5,000 feet All other modes: QDR = 4,000 feet NEWQD > 226.8 kilograms Railcars: QDR = 1,524 meters All other modes: QDR = 1,219 meters Bombs and projectiles with caliber of 5-inches (127-millimeters) or greater: QDR = 4,000 feet QDR = 1,219 meters **Facilities:** NEWQD ≤ 15,000 pounds QDR = 2,500 feet NEWQD ≤ 6,804 kilograms QDR = 762 meters NEWQD > 15,000 pounds ≤ 55,285 pounds QDR = 4,000 feet NEWQD > 6,804 kilograms ≤ 25,077 kilograms QDR = 1,219 meters NEWQD > 55,285 pounds QDR = $K105W^{1/3}$ NEWQD > 25,077 kilograms QDR = $K(m)41.65Q^{1/3}$
1.2[1] and 1.6	**2,500** **(762)**	2,500 (762)
1.3	**600** **(183)**	$K15W^{1/3}$ with minimum of 600 feet $K(m)5.95Q^{1/3}$ with a minimum of 183 meters
1.4	**300** **(92)**	300 (92)

1. Emergency withdrawal distances do not consider the potential flight range of propulsion units.
2. For known amount of AE, these distances may be substituted using the Blast Overpressure, Hazardous Fragmentation Distance, and/or Maximum Fragmentation Distance Ranges.

Table 3-5
EMERGENCY WITHDRAWAL DISTANCES FOR NONESSENTIAL PERSONNEL

Table 3-6. Quantity Distances Ranges for HD 1.3, 1.4, or 1.6. AE.

NEWQD Pounds (Kilograms)	Minimal Quantity Distance Range Feet (Meters)
≤ 1,000	75
≤ (454)	(23)
1,500	82
(680)	(25)
2,000	89
(907)	(27)
3,000	101
(1,361)	(31)
5,000	117
(2,268)	(36)
7,000	130
(3,175)	(40)
10,000	145
(4,536)	(44)
15,000	164
(6,804)	(50)
20,000	180
(9,072)	(55)
30,000	204
(13,608)	(62)
50,000	240
(22,680)	(73)
70,000	268
(31,751)	(82)
100,000	300
(45,359)	(91)
150,000	346
(68,039)	(105)
200,000	385
(90,718)	(117)
300,000	454
(136,077)	(138)
500,000	569
(226,795)	(174)

Table 3-6
QUANTITY DISTANCE RANGES FOR HD 1.3, HD 1.4, AND HD 1.6

Table 3-7. Anticipated Effects for a Single Buried Ordnance Item (Sheet 1 of 5).

NEWQD Pounds (Kilograms)		Burial Depth Range Feet (Meters) >1 ≤3 (0.3-0.91)				Burial Depth Range Feet (Meters) >3 ≤5 (0.91-1.5)			
>	≤	Debris Ejection[1] Feet (Meters)	Crater Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)		Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)	
0	5	286	8	350	50	CA[4]	5	N/A	N/A
(0.0)	(2.3)	(87)	(2)	(107)	(15)	CA[4]	(2)	N/A	N/A
5	10	344	10	500	150	362	11	150	50
(2.3)	(4.5)	(105)	(3)	(152)	(46)	(110)	(3)	(46)	(15)
10	20	412	13	700	250	434	13	250	80
(4.5)	(9.1)	(126)	(4)	(213)	(76)	(132)	(4)	(76)	(24)
20	30	458	14	850	350	482	15	350	150
(9.1)	(13.6)	(140)	(4)	(259)	(107)	(147)	(5)	(107)	(46)
30	40	494	15	1,000	425	520	16	425	180
(13.6)	(18.1)	(151)	(5)	(305)	(130)	(158)	(5)	(130)	(55)
40	50	524	16	1,100	480	552	17	480	200
(18.1)	(22.7)	(160)	(5)	(335)	(146)	(168)	(5)	(146)	(61)
50	100	629	20	1,450	800	662	21	800	400
(22.7)	(45.4)	(192)	(6)	(442)	(244)	(202)	(6)	(244)	(122)
100	200	754	24	1,950	1,200	794	26	1,200	700
(45.4)	(91)	(230)	(7)	(594)	(366)	(242)	(8)	(366)	(213)
200	300	839	27	2,250	1,450	883	29	1,450	900
(91)	(136)	(256)	(8)	(686)	(442)	(269)	(9)	(442)	(274)
300	400	905	30	2,550	1,750	952	32	1,750	1,150
(136)	(181)	(276)	(9)	(777)	(533)	(290)	(10)	(533)	(351)
400	500	959	32	2,800	1,900	1,010	34	1,900	1,300
(181)	(227)	(292)	(10)	(853)	(579)	(308)	(10)	(579)	(396)
500	1,000	1,151	39	3,280	2,700	1,211	41	2,700	1,950
(227)	(454)	(351)	(12)	(1,000)	(823)	(369)	(12)	(823)	(594)
1,000	2,000	1,381	47	4,133	3,700	1,453	51	3,700	2,800
(454)	(907)	(421)	(14)	(1,260)	(1,128)	(443)	(16)	(1,128)	(853)
2,000	3,000	1,536	53	4,731	4,400	1,616	57	4,400	3,450
(907)	(1,361)	(468)	(16)	(1,442)	(1,341)	(493)	(17)	(1,341)	(1,052)
3,000	4,000	1,656	58	5,207	5,000	1,743	62	5,000	4,100
(1,361)	(1,814)	(505)	(18)	(1,587)	(1,524)	(531)	(19)	(1,524)	(1,250)
4,000	5,000	1,756	61	5,609	5,500	1,848	66	5,500	4,600
(1,814)	(2,268)	(535)	(19)	(1,710)	(1,676)	(563)	(20)	(1,676)	(1,402)
5,000	7,000	1,918	68	6,274	6,274	2,019	73	6,274	5,300
(2,268)	(3,175)	(585)	(21)	(1,912)	(1,912)	(615)	(22)	(1,912)	(1,615)
7,000	10,000	2,106	75	7,067	7,067	2,217	80	7,067	6,300
(3,175)	(4,536)	(642)	(23)	(2,154)	(2,154)	(677)	(24)	(2,154)	(1,920)
10,000	20,000	2,527	92	8,903	8,903	2,659	98	8,903	8,500
(4,536	(9,072)	(770)	(28)	(2,714)	(2,714)	(810)	(30)	(2,714)	(2,591)
20,000	30,000	2,810	103	10,192	10,192	2,958	110	10,192	10,000
(9,072)	(13,608)	(856)	(32)	(3,107)	(3,107)	(902)	(34)	(3,107)	(3,048)

1 Maximum soil debris ejection radius derived from higher burial depth range.
2 Expected crater or camouflet diameter.
3 Overpressure equivalent to K328 or greater (left column is low range burial depth, right column is high range burial depth).
4 CA indicates camouflet formation is expected (diameter shown in right column).

Table 3-7:1
ANTICIPATED EFFECTS FOR A SINGLE BURIED ORDNANCE ITEM (SHEET 1 OF 5)

Table 3-7. Anticipated Effects for a Single Buried Ordnance Item (Sheet 2 of 5).

NEWQD Pounds (Kilograms)		Burial Depth Range Feet (Meters)				Burial Depth Range Feet (Meters)			
		>5 ≤10 (1.5-3.0)				>10 ≤15 (3.0-4.6)			
>	≤	Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)		Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)	
5	10	CA[4]	3	N/A		N/A	N/A	N/A	
(2.3)	(4.5)	CA[4]	(1)	N/A		N/A	N/A	N/A	
10	20	CA[4]	3	N/A		N/A	N/A	N/A	
(4.5)	(9.1)	CA[4]	(1)	N/A		N/A	N/A	N/A	
20	30	CA[4]	4	N/A		N/A	N/A	N/A	
(9.1)	(13.6)	CA[4]	(1)	N/A		N/A	N/A	N/A	
30	40	CA[4]	4	N/A		N/A	N/A	N/A	
(13.6)	(18.1)	CA[4]	(1)	N/A		N/A	N/A	N/A	
40	50	591	19	200	50	CA[4]	9	N/A	
(18.1)	(22.7)	(180)	(6)	(61)	(15)	CA[4]	(3)	N/A	
50	100	709	23	400	100	CA[4]	10	N/A	
(22.7)	(45.4)	(216)	(7)	(122)	(30)	CA[4]	(3)	N/A	
100	200	851	29	700	200	886	31	200	80
(45.4)	(91)	(259)	(9)	(213)	(61)	(270)	(9)	(61)	(24)
200	300	946	32	900	300	986	34	300	120
(91)	(136)	(288)	(10)	(274)	(91)	(301)	(10)	(91)	(37)
300	400	1,021	35	1,150	450	1,063	37	450	180
(136)	(181)	(311)	(11)	(351)	(137)	(324)	(11)	(1370	(55)
400	500	1,082	37	1,300	500	1,127	39	500	200
(181)	(227)	(330)	(11)	(296)	(152)	(344)	(12)	(152)	(61)
500	1,000	1,298	45	1,950	950	1,352	48	950	400
(227)	(454)	(396)	(14)	(594)	(290)	(412)	(15)	(290)	(122)
1,000	2,000	1,557	55	2,800	1,550	1,622	59	1,550	850
(454)	(907)	(475)	(17)	(853)	(472)	(494)	(18)	(472)	(259)
2,000	3,000	1,732	62	3,450	2,100	1,804	66	2,100	1,200
(907)	(1,361)	(528)	(19)	(1,052)	(640)	(550)	(20)	(640)	(366)
3,000	4,000	1,868	68	4,100	2,450	1,945	72	2,450	1,500
(1,361)	(1,814)	(569)	(21)	(1,250)	(747)	(593)	(22)	(747)	(457)
4,000	5,000	1,981	72	4,600	2,850	2,063	76	2,850	1,900
(1,814)	(2,268)	(604)	(22)	(1,402)	(869)	(629)	(23)	(869)	(579)
5,000	7,000	2,163	80	5,300	3,600	2,253	84	3,600	2,450
(2,268)	(3,175)	(659)	(24)	(1,615)	(1,097)	(687)	(26)	(1,097)	(747)
7,000	10,000	2,376	88	6,300	4,400	2,474	93	4,400	3,200
(3,175)	(4,536)	(724)	(27)	(1,920)	(1,341)	(754)	(28)	(1,341)	(975)
10,000	20,000	2,850	108	8,500	6,400	2,968	114	6,400	4,800
(4,536	(9,072)	(869)	(33)	(2,591)	(1,951)	(905)	(35)	(1,951)	(1,463)
20,000	30,000	3,170	121	10,000	7,800	3,301	128	7,800	6,100
(9,072)	(13,608)	(966)	(37)	(3,048)	(2,377)	(1,006)	(39)	(2,377)	(1,859)

1 Maximum soil debris ejection radius derived from higher burial depth range.
2 Expected crater or camouflet diameter.
3 Overpressure equivalent to K328 or greater (left column is low range burial depth, right column is high range burial depth).
4 CA indicates camouflet formation is expected (diameter shown in right column).

Table 3-7:2
ANTICIPATED EFFECTS FOR A SINGLE BURIED ORDNANCE ITEM (SHEET 2 OF 5)

Table 3-7. Anticipated Effects for a Single Buried Ordnance Item (Sheet 3 of 5).

NEWQD Pounds (Kilograms)		Burial Depth Feet (Meters) >15 ≤20 (4.6-6.1)				Burial Depth Feet (Meters) >20 ≤30 (6.1-9.1)			
>	≤	Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)		Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)	
100	200	CA[4]	13	N/A		N/A	N/A	N/A	
(45.4)	(91)	CA[4]	(4)	N/A		N/A	N/A	N/A	
200	300	1,014	35	120	50	CA[4]	15	N/A	
(91)	(136)	(309)	(11)	(37)	(15)	CA[4]	(5)	N/A	
300	400	1,094	38	180	70	CA[4]	16	N/A	
(136)	(181)	(333)	(12)	(55)	(21)	CA[4]	(5)	N/A	
400	500	1,160	41	200	150	CA[4]	17	N/A	
(181)	(227)	(354)	(12)	(61)	(46)	CA[4]	(5)	N/A	
500	1,000	1,391	50	400	250	1,449	53	250	90
(227)	(454)	(424)	(15)	(122)	(76)	(442)	(16)	(76)	(27)
1,000	2,000	1,669	61	850	500	1,738	64	500	200
(454)	(907)	(509)	(19)	(259)	(152)	(530)	(20)	(152)	(61)
2,000	3,000	1,856	69	1,200	750	1,933	72	750	250
(907)	(1,361)	(566)	(21)	(366)	(229)	(589)	(22)	(229)	(76)
3,000	4,000	2,002	74	1,500	900	2,085	79	900	350
(1,361)	(1,814)	(610)	(23)	(457)	(274)	(636)	(24)	(274)	(107)
4,000	5,000	2,123	79	1,900	1,300	2,211	84	1,300	600
(1,814)	(2,268)	(647)	(24)	(579)	(396)	(674)	(26)	(396)	(183)
5,000	7,000	2,319	87	2,450	1,650	2,415	92	1,650	800
(2,268)	(3,175)	(707)	(27)	(747)	(503)	(736)	(28)	(503)	(244)
7,000	10,000	2,546	97	3,200	2,200	2,652	102	2,200	1,200
(3,175)	(4,536)	(776)	(30)	(975)	(671)	(808)	(31)	(671)	(366)
10,000	20,000	3,054	118	4,800	3,600	3,181	125	3,600	2,200
(4,536	(9,072)	(931)	(36)	(1,463)	(1,097)	(970)	(38)	(1,097)	(671)
20,000	30,000	3,397	133	6,100	4,800	3,538	140	4,800	3,000
(9,072)	(13,608)	(1,035)	(41)	(1,859)	(1,463)	(1,078)	(43)	(1,463)	(914)

1 Maximum soil debris ejection radius derived from higher burial depth range.
2 Expected crater or camouflet diameter.
3 Overpressure equivalent to K328 or greater (left column is low range burial depth, right column is high range burial depth).
4 CA indicates camouflet formation is expected (diameter shown in right column).

Table 3-7:3

ANTICIPATED EFFECTS FOR A SINGLE BURIED ORDNANCE ITEM (SHEET 3 OF 5)

Table 3-7. Anticipated Effects for a Single Buried Ordnance Item (Sheet 4 of 5).

NEWQD Pounds (Kilograms)		Burial Depth Range Feet (Meters) >30 ≤40 (9-12)				Burial Depth Range Feet (Meters) >40 ≤80 (12-24)			
>	≤	Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meters)		Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Distance for Overpressure[3] Feet (Meteres)	
500	1,000	CA[4]	21	N/A		N/A	N/A	N/A	
(227)	(454)	CA[4]	(6)	N/A		N/A	N/A	N/A	
1,000	2,000	1,789	67	200	80	CA[4]	27	N/A	
(454)	(907)	(545)	(20)	(61)	(24)	CA[4]	(8)	N/A	
2,000	3,000	1,990	75	250	100	CA[4]	29	N/A	
(907)	(1,361)	(607)	(23)	(76)	(30)	CA[4]	(9)	N/A	
3,000	4,000	2,146	82	350	150	CA[4]	32	N/A	
(1,361)	(1,814)	(654)	(25)	(107)	(46)	CA[4]	(10)	N/A	
4,000	5,000	2,275	87	600	200	CA[4]	34	N/A	
(1,814)	(2,268)	(693)	(27)	(183)	(61)	CA[4]	(10)	N/A	
5,000	7,000	2,485	86	800	350	CA[4]	37	N/A	
(2,268)	(3,175)	(757)	(26)	(244)	(107)	CA[4]	(11)	N/A	
7,000	10,000	2,729	106	1,200	600	2,925	117	600	300
(3,175)	(4,536)	(832)	(32)	(366)	(183)	(892)	(36)	(183)	(91)
10,000	20,000	3,274	130	2,200	1,250	3,509	143	1,250	500
(4,536	(9,072)	(999)	(40)	(671)	(381)	(1,070)	(44)	(381)	(152)
20,000	30,000	3,641	146	3,000	1,900	3,903	160	1,900	800
(9,072)	(13,608)	(1,110)	(45)	(914)	(579)	(1,190)	(49)	(579)	(244)

1 Maximum soil debris ejection radius derived from higher burial depth range.
2 Expected crater or camouflet diameter.
3 Overpressure equivalent to K328 or greater (left column is low range burial depth, right column is high range burial depth).
4 CA indicates camouflet formation is expected (diameter shown in right column).

Table 3-7:4

ANTICIPATED EFFECTS FOR A SINGLE BURIED ORDNANCE ITEM (SHEET 4 OF 5)

Table 3-7. Anticipated Effects for a Single Buried Ordnance Item (Sheet 5 of 5).

NEWQD Pounds (Kilograms)		Burial Depth Feet (Meters) >80 ≤120 (24-37)				Burial Depth Feet (Meters) >120 ≤150 (37-46)		
>	≤	Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Protection for Overpressure[3] Feet (Meters)		Debris Ejection[1] Feet (Meters)	Crater/ Camouflet Diameter[2] Feet (Meters)	Minimal Protection for Overpressure[3] Feet (Meters)
7,000	10,000	CA[4]	43	N/A		N/A	N/A	N/A
(3,175)	(4,536)	CA[4]	(13)	N/A		N/A	N/A	N/A
10,000	20,000	3,654	151	300	200	CA[4]	52	N/A
(4,536	(9,072)	(1,114)	(46)	(91)	(61)	CA[4]	(16)	N/A
20,000	30,000	4,064	(169)	800	200	CA[4]	58	N/A
(9,072)	(13,608)	(1,239)	(52)	(244)	(61)	CA[4]	(18)	N/A

1 Maximum soil debris ejection radius derived from higher burial depth range.
2 Expected crater or camouflet diameter.
3 Overpressure equivalent to K328 or greater (left column is low range burial depth, right column is high range burial depth).
4 CA indicates camouflet formation is expected (diameter shown in right column).

Table 3-7:4
ANTICIPATED EFFECTS FOR A SINGLE BURIED ORDNANCE ITEM (SHEET 5 OF 5)

Table 3-8. Distances to Protect Against Ground Shock
For AE Located in an Underground Storage Configuration (Sheet 1 of 3).

NEWQD Pounds (Kilograms)	Soil Feet (Meters)	Weak Rock Feet (Meters)	Moderate to Strong Rock Feet (Meters)
1 (0.45)	3 (0.9)	13 (4)	15 (5)
3 (1.4)	4 (1)	22 (7)	24 (7)
5 (2.3)	5 (2)	27 (8)	30 (9)
25 (11)	10 (3)	55 (17)	62 (19)
80 (36)	17 (5)	92 (28)	103 (31)
150 (68)	23 (7)	121 (37)	136 (41)
300 (136)	31 (9)	164 (50)	185 (56)
500 (227)	39 (12)	205 (62)	231 (70)
700 (318)	45 (14)	238 (73)	268 (82)
1,000 (454)	53 (16)	278 (85)	313 (95)
1,500 (680)	63 (19)	333 (101)	375 (114)
2,000 (907)	71 (22)	378 (115)	425 (130)
2,500 (1,134)	79 (24)	416 (127)	469 (143)
3,500 (1,588)	91 (28)	483 (147)	544 (166)
4,500 (2,041)	102 (31)	539 (164)	607 (185)
6,000 (2,722)	116 (35)	612 (187)	689 (210)
8,000 (3,629)	131 (40)	695 (212)	782 (238)
10,000 (4,536)	145 (44)	766 (233)	863 (263)
13,000 (5,897)	163 (50)	860 (262)	969 (295)
16,000 (7,258)	178 (54)	943 (287)	1,061 (323)
20,000 (9,072)	198 (60)	1,040 (317)	1,171 (357)
25,000 (11,340)	217 (66)	1,147 (350)	1,292 (394)
30,000 (13,608)	235 (72)	1,243 (379)	1,400 (427)
35,000 (15,876)	252 (77)	1,330 (405)	1,498 (457)

Table 3-8:1
DISTANCES TO PROTECT AGAINST GROUND SHOCK (1 OF 3)

Table 3-8. Distance to Protect for Ground Shock for Buried AE (Sheet 2 of 3).

NEWQD Pounds (Kilograms) >	NEWQD Pounds (Kilograms) ≤	Soil Description: Dry Sandy/ Loose Sandy Clay[1] Feet (Meters)	Soil Description: Moderate to Strong Rock[2] Feet (Meters)	Soil Description: Plastic Clay[3] Feet (Meters)
0 (0)	1 (0.454)	34 (10)	138 (42)	160 (49)
1 (0.454)	3 (1.4)	49 (15)	199 (36)	230 (70)
3 (1.4)	5 (2.3)	58 (18)	236 (72)	273 (83)
5 (2.3)	10 (5)	73 (22)	287 (87)	344 (105)
10 (5)	20 (9)	92 (28)	375 (114)	433 (132)
20 (9)	30 (14)	106 (32)	429 (131)	496 (151)
30 (14)	40 (18)	117 (36)	472 (144)	546 (166)
40 (18)	50 (23)	126 (38)	509 (155)	588 (179)
50 (23)	100 (45)	158 (48)	641 (195)	740 (226)
100 (45)	200 (91)	199 (61)	807 (246)	933 (284)
200 (91)	300 (136)	228 (69)	924 (282)	1,068 (326)
300 (136)	400 (181)	251 (77)	1,017 (310)	1,175 (358)
400 (181)	500 (227)	270 (820	1,095 (334)	1,266 (386)
500 (227)	600 (272)	287 (87)	1,164 (355)	1,345 (410)
600 (272)	700 (318)	303 (92)	1,226 (374)	1,416 (432)

1 Loose, moist with some air voids.
2 Dense, low moisture with no air voids.
3 Thick past-like consistency with no air voids.

Table 3-8:2
DISTANCES TO PROTECT AGAINST GROUND SHOCK (2 OF 3)

Table 3-8. Distance to Protect for Ground Shock
for Buried AE (Sheet 3 of 3).

NEWQD Pounds (Kilograms)		Soil Description: Dry Sand/ Loose Sandy Clay[1] Feet (Meters)	Soil Description: Moderate to Strong Rock[2] Feet (Meters)	Soil Description: Plastic Clay[3] Feet (Meters)
>	≤			
700	800	316	1,281	1,481
(318)	(362)	(96)	(390)	(451)
800	900	329	1,333	1,540
(362)	(408)	(100)	(406)	(469)
900	1,000	341	1,380	1,595
(408)	(454)	(104)	(421)	(486)
1,000	2,000	429	1,739	2,010
(454)	(907)	(131)	(530)	(613)
2,000	3,000	491	1,991	2,301
(907)	(1,361)	(150)	(607)	(701)
3,000	4,000	541	2,191	2,532
(1,361)	(1,814)	(165)	(668)	(772)
4,000	5,000	583	2,360	2,728
(1,814)	(2,268)	(178)	(719)	(831)
5,000	6,000	619	2,508	2,899
(2,268)	(2,722)	(189)	(764)	(884)
6,000	7,000	652	2,640	3,051
(2,722)	(3,175)	(199)	(805)	(930)
7,000	8,000	681	2,760	3,190
(3,175)	(3,629)	(208)	(841)	(972)
8,000	9,000	709	2,871	3,318
(3,629)	(4,082)	(216)	(875)	(1,011)
9,000	10,000	734	2,974	3,437
(4,082)	(4,536)	(224)	(906)	(1,048)
10,000	15,000	840	3,404	3,934
(4,536)	(6,804)	(256)	(1,038)	(1,199)
15,000	20,000	925	3,747	4,330
(6,804)	(6,096)	(282)	(1,142)	(1,320)
20,000	30,000	1,059	4,289	4,956
(6,096)	(13, 608)	(323)	(1,307)	(1,511)

1 Loose, moist with some air voids.
2 Dense, low moisture with no air voids.
3 Thick past-like consistency with no air voids.

Table 3-8:3
DISTANCES TO PROTECT AGAINST GROUND SHOCK (3 OF 3)

Table 3-9. Critical Cover Thickness and Potential Flyrock Event Throw Distance.

NEWQD Pounds (Kilograms)	Required Critical Cover Thickness K3.5 Feet (K(m)1.38) (Meters)	QDR for Maximum Anticipated Flyrock Throw Distance K625 Feet (K(m)248) (Meters)
100	16	2,910
(45)	(5)	(887)
200	20	3,655
(91)	(6)	(1,114)
400	26	4,605
(181)	(8)	(1,404)
600	30	5,271
(272)	(9)	(1,607)
800	32	5,802
(363)	(10)	(1,768)
1,000	35	6,250
(454)	(11)	(1,905)
2,000	44	7,875
(907)	(13)	(2,400)
4,000	56	9,921
(1,814)	(17)	(3,024)
6,000	64	11,357
(2,722)	(20)	(3,462)
8,000	70	12,500
(3,629)	(21)	(3,810)
10,000	75	13,465
(4,536)	(23)	(4,104)
15,000	86	15,414
(6,804)	(26)	(4,698)
20,000	95	16,965
(9,072)	(29)	(5,171)
25,000	102	18,275
(11,340)	(31)	(5,570)
30,000	109	19,420
(13,608)	(33)	(5,919)
35,000	114	20,444
(15,876)	(35)	(6,231)
40,000	120	21,375
(18,144)	(37)	(6,515)
45,000	124	22,230
(20,412)	(38)	(6,776)
50,000	129	23,025
(22,680)	(39)	(7,018)
60,000	137	24,468
(27,216)	(42)	(7,458)
80,000	151	26,930
(36,288)	(46)	(8,208)
100,000	162	29,0010
(45,360)	(49)	(8,842)

Table 3-9

CRITICAL COVER THICKNESS AND PROTENTIAL FLYROCK EVENT THROW DISTANCE

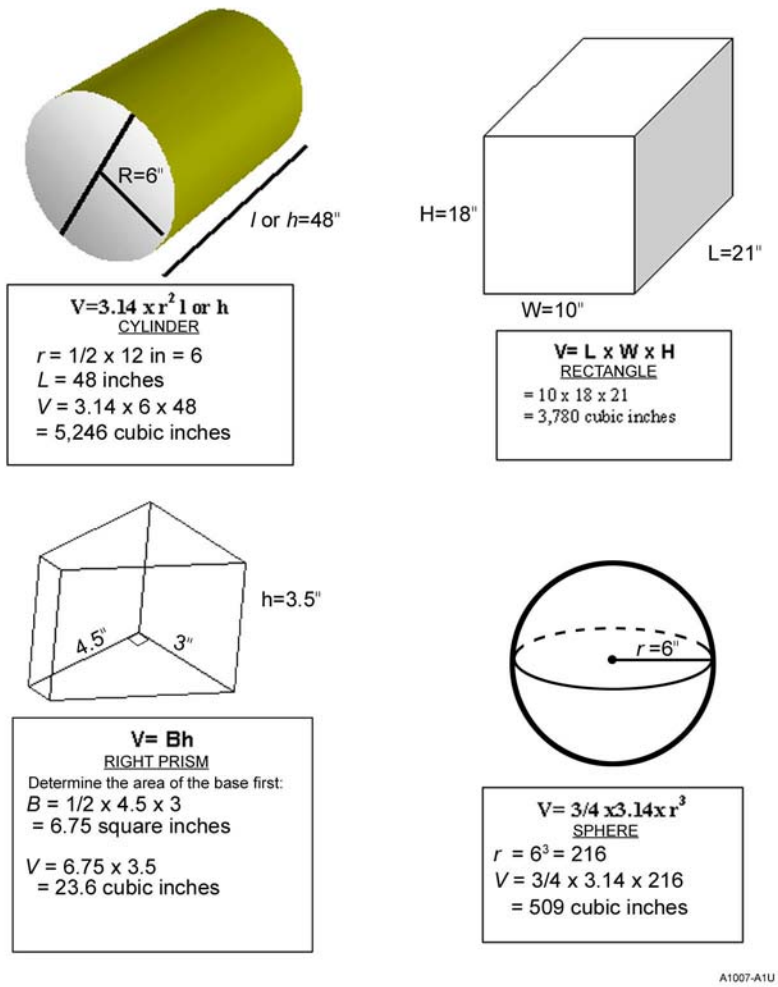


Figure A1. Equations (Sheet 1 of 2)

Figure A-1:1

EQUATIONS (SHEET 1 OF 2)

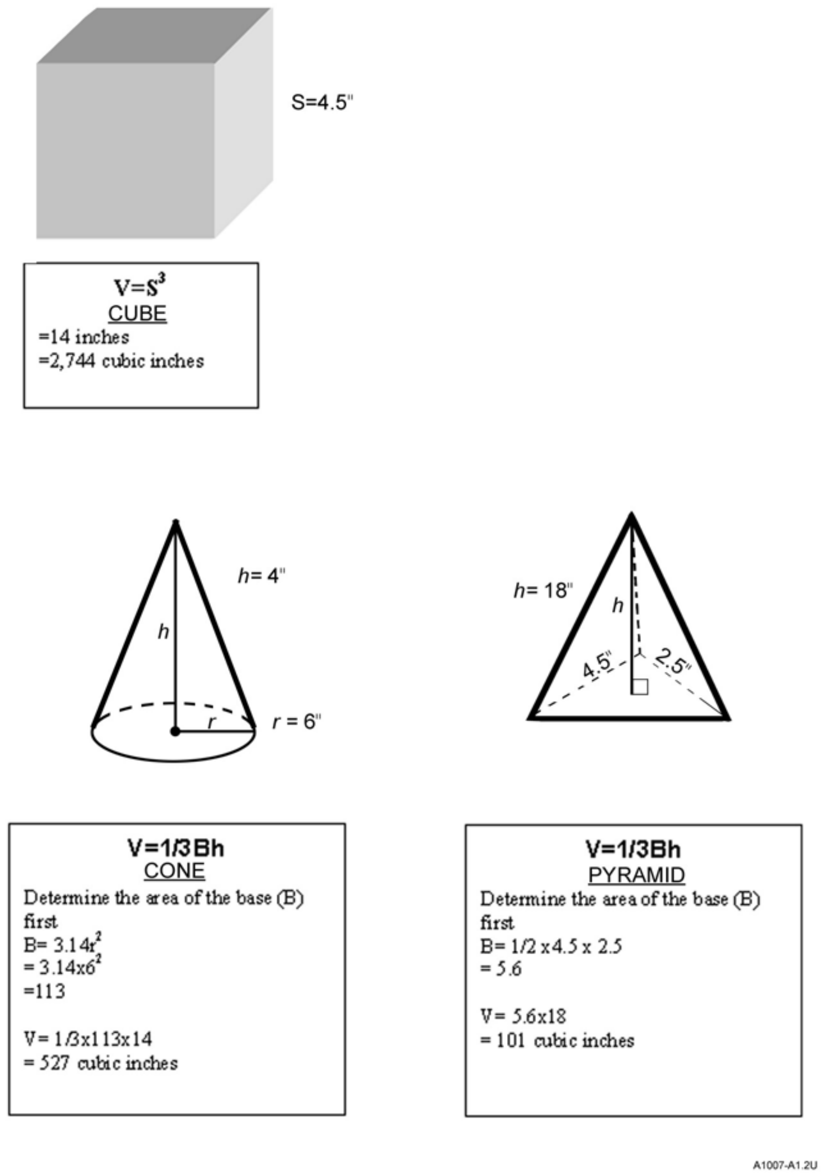


Figure A-1 Equations (Sheet 2 of 2)

Figure A-1:2

EQUATIONS (SHEET 2 OF 2)

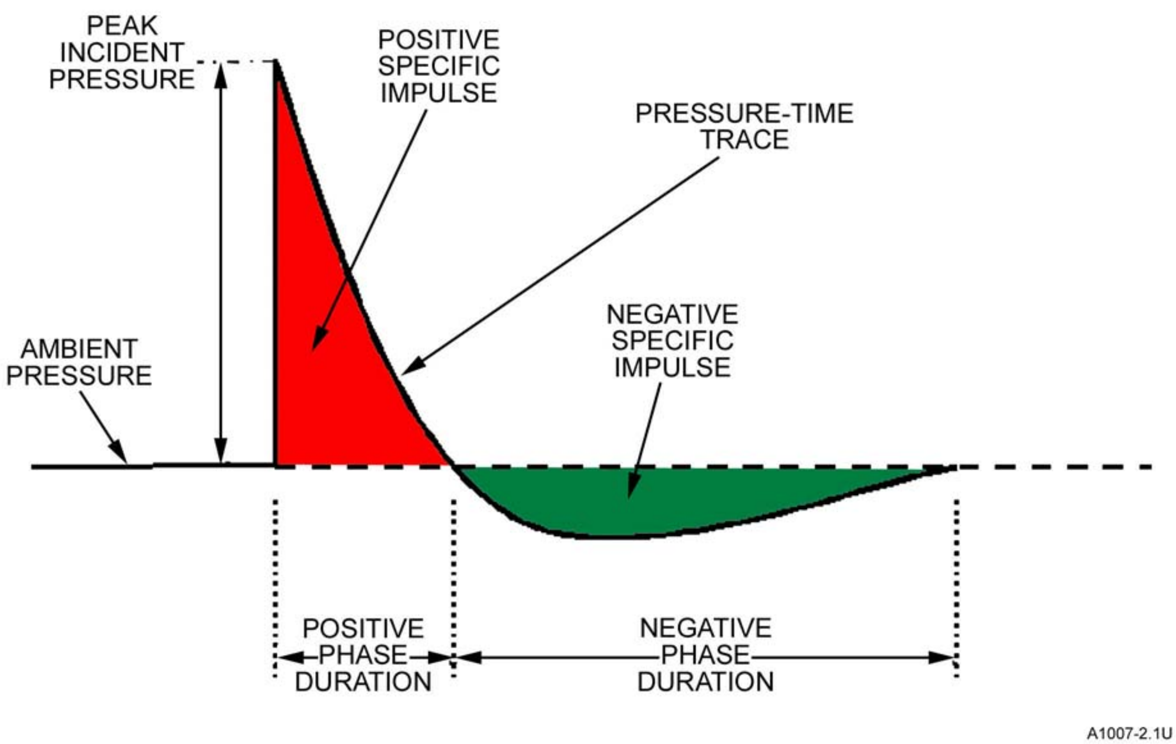


Figure 2-1. Typical Blast Wave Time Record

Figure 2-1

TYPICAL BLAST WAVE TIME RECORD

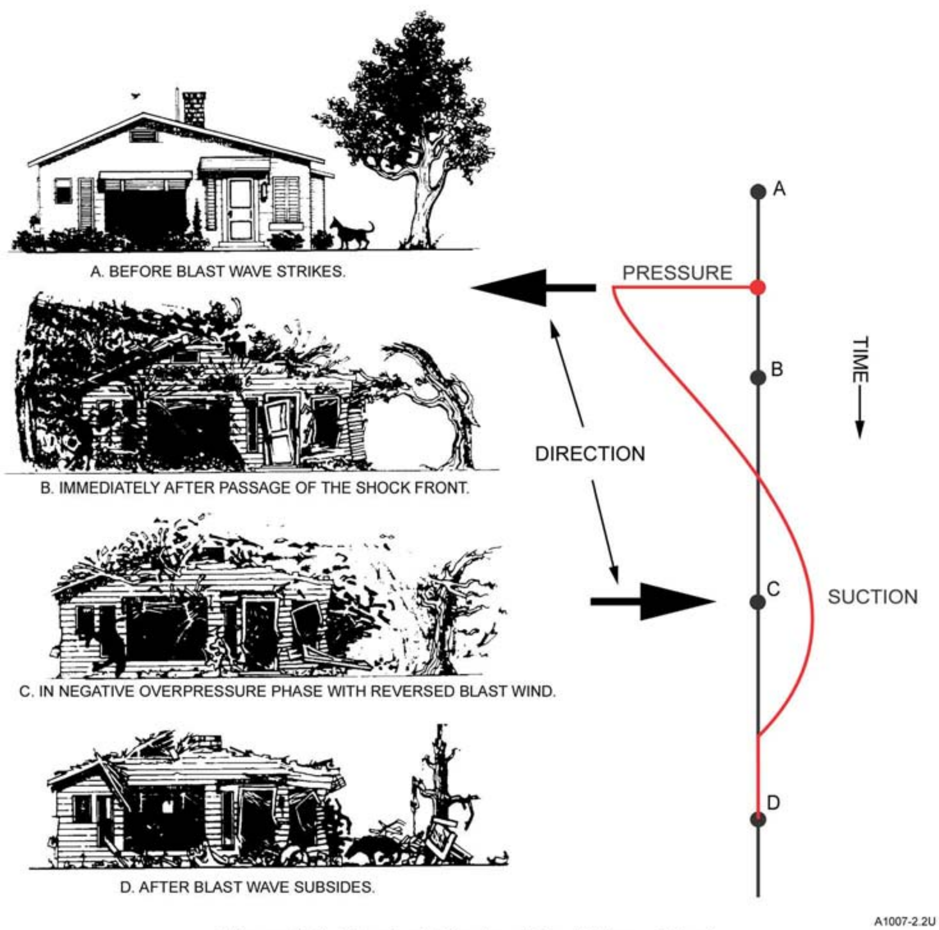


Figure 2-2. Physical Effects of Blast Wave Effects

Figure 2-2

PHYSICAL EFFECTS OF BLAST WAVE EFFECTS

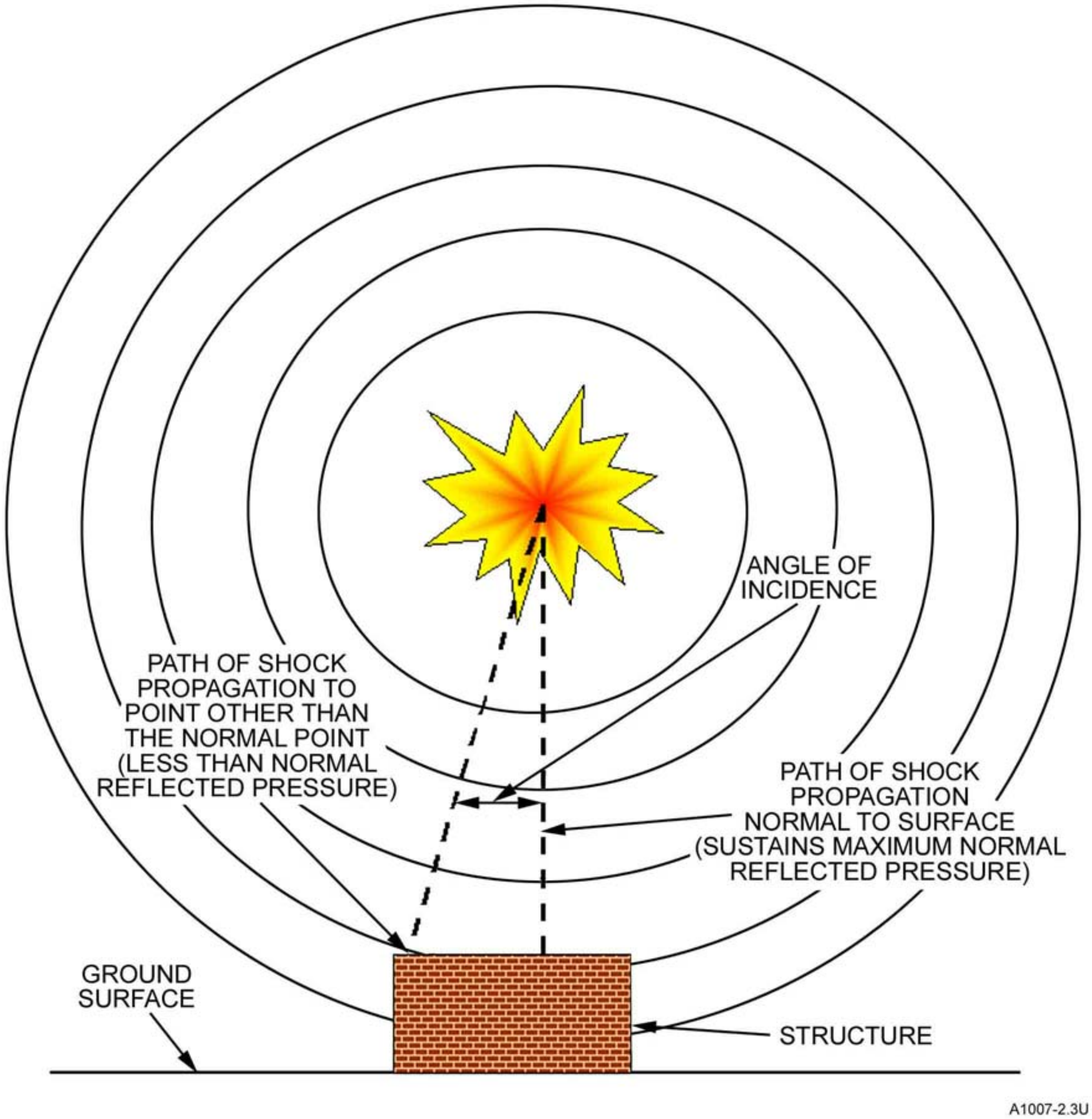


Figure 2-3. Free-Air Burst Explosion

Figure 2-3

FREE-AIR BURST EXPLOSION

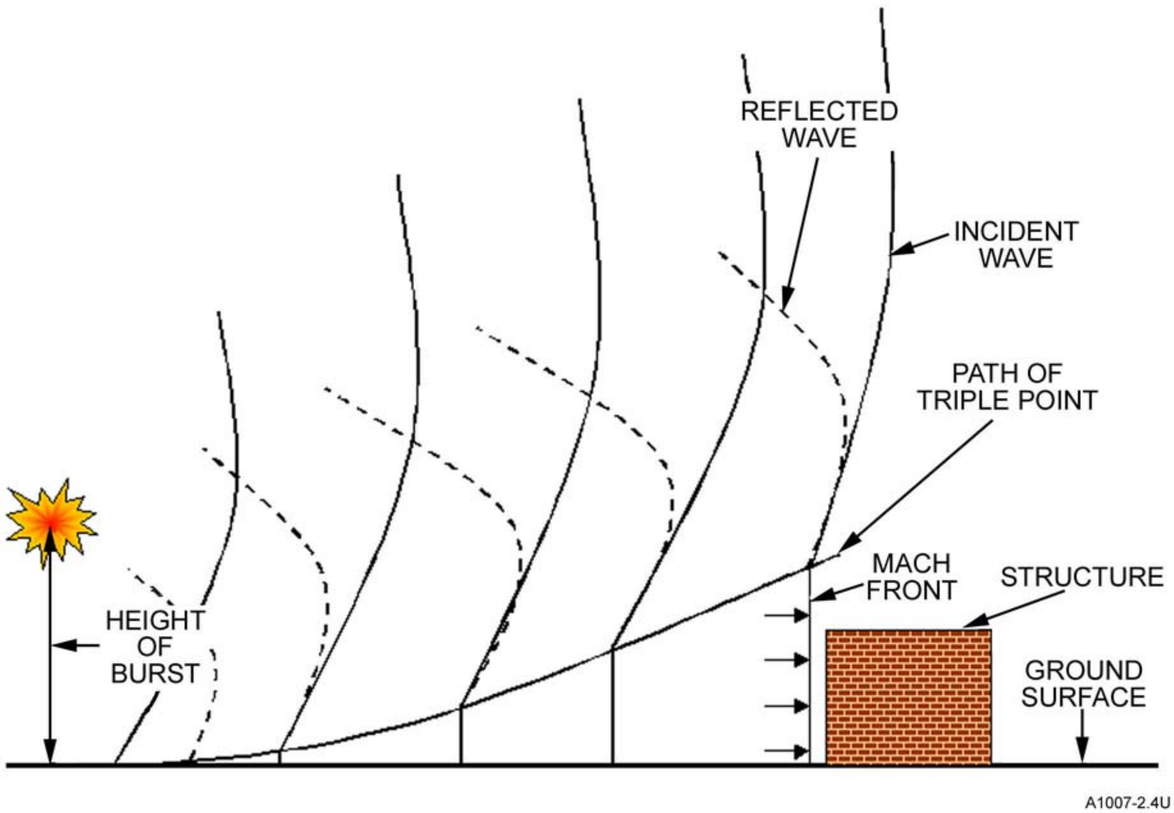


Figure 2-4. Air Burst Explosion

Figure 2-4

AIR BURST EXPLOSION

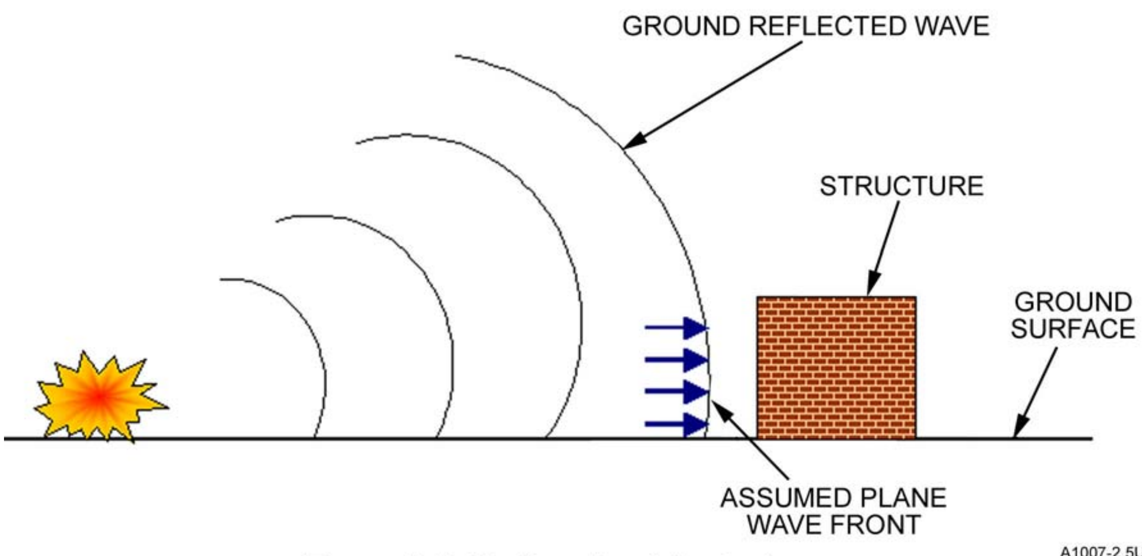


Figure 2-5. Surface Burst Explosion

Figure 2-5

SURFACE BURST EXPLOSION

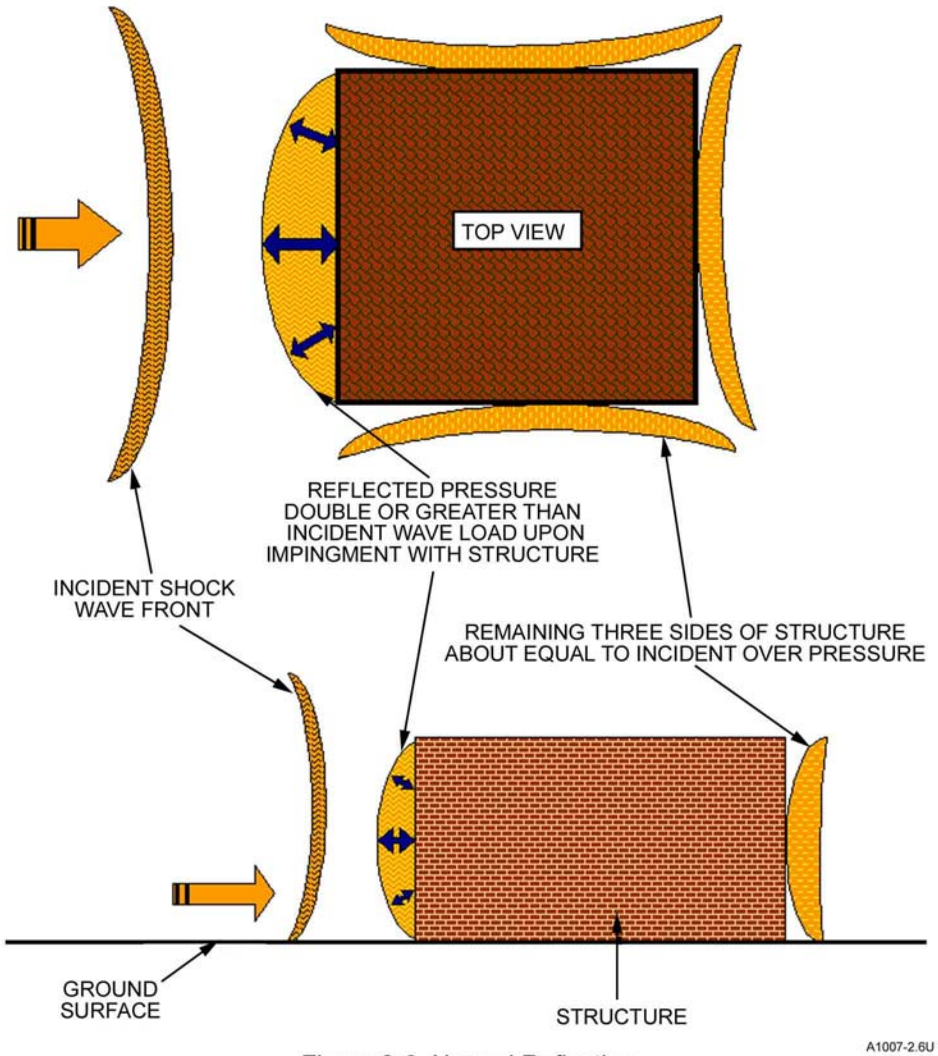


Figure 2-6. Normal Reflection

Figure 2-6

NORMAL REFLECTION

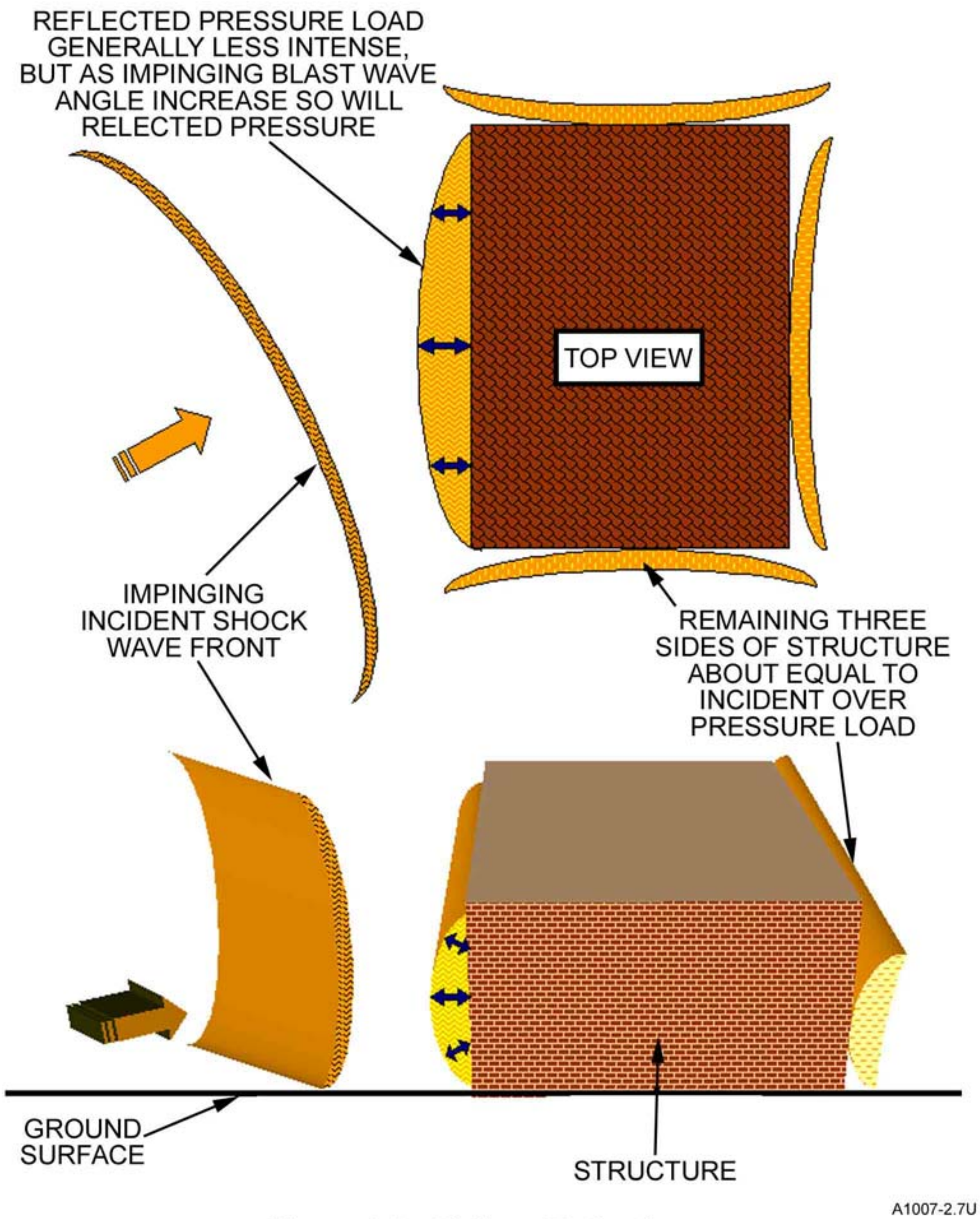


Figure 2-7. Oblique Reflection

Figure 2-7

OBLIQUE REFLECTION

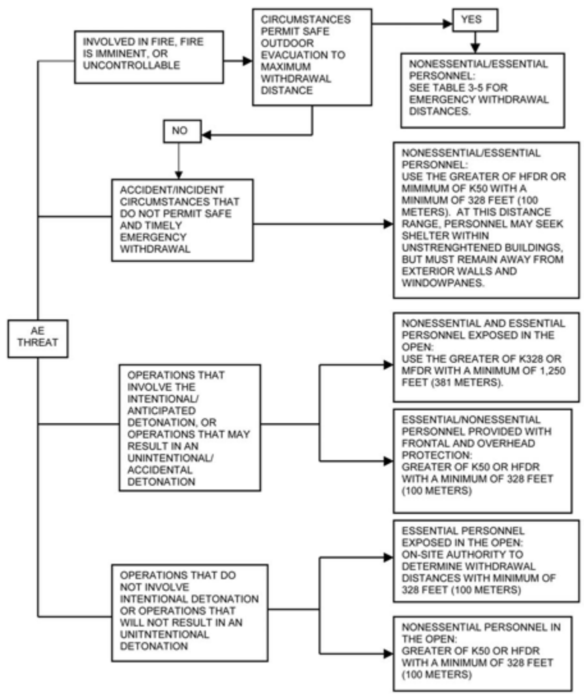


Figure 3-1. Event Flow Tree for Typical AE Threat/Incident

Figure 3-1

EVENT FLOW TREE FOR TYPICAL AE THREAT/INCIDENT

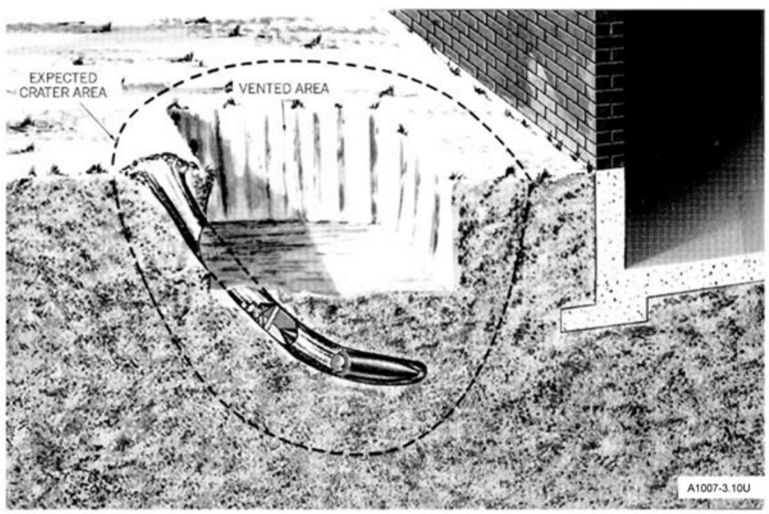
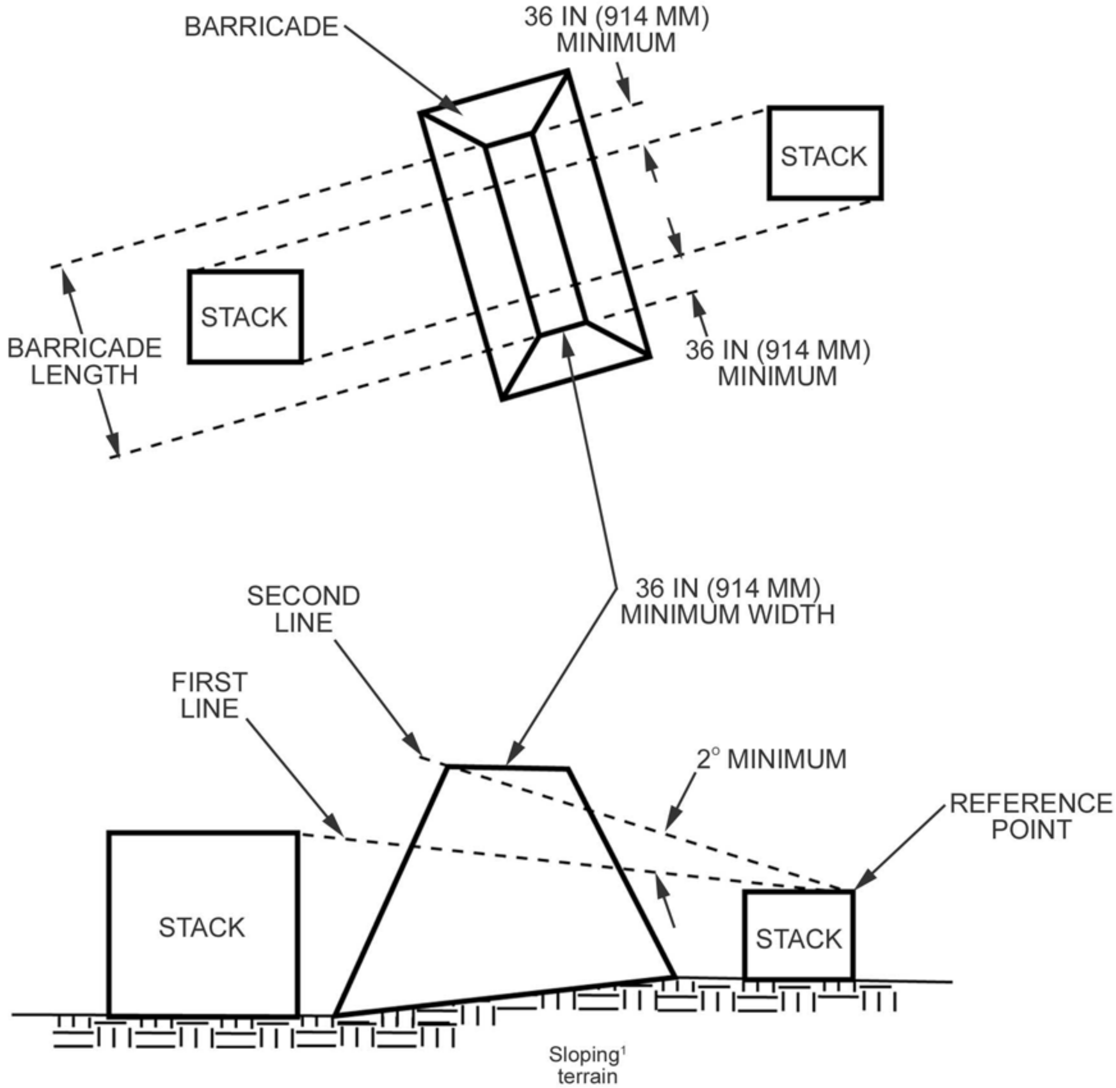


Figure 3-10. Method of Venting

Figure 3-10

METHOD OF VENTING



1. This illustration is for sloping terrain; however, a similar approach is used for level terrain.

A1007-3.11U

Figure 3-11. Determination of Barricade Length and Height

Figure 3-11

DETERMINATION OF BARRICADE LENGTH AND HEIGHT

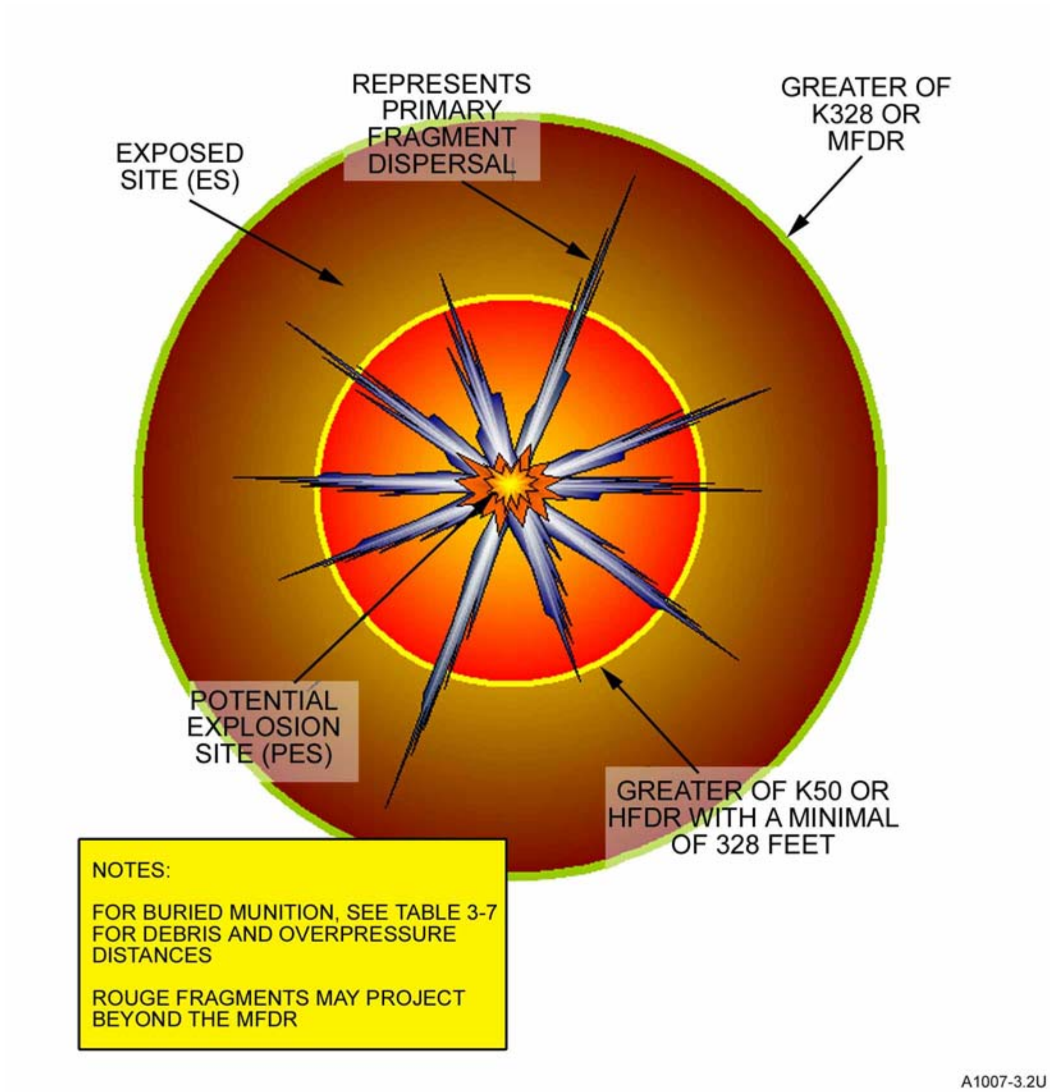


Figure 3-2. Relationship Between the QDRs and Primary Fragment Dispersal

Figure 3-2

RELATIONSHIP BETWEEN THE QDRS AND PRIMARY FRAGMENT DISPERSAL

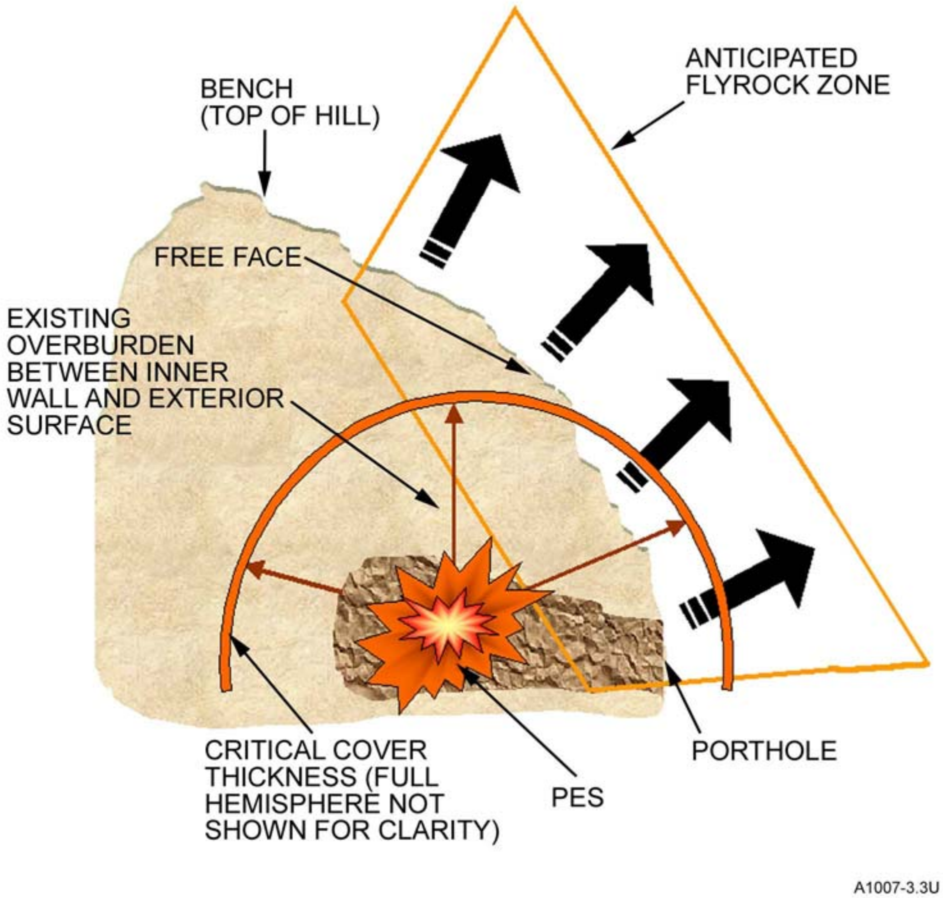


Figure 3-3. Shallow Cavern/Cave

Figure 3-3

SHALLOW CAVERN/CAVE

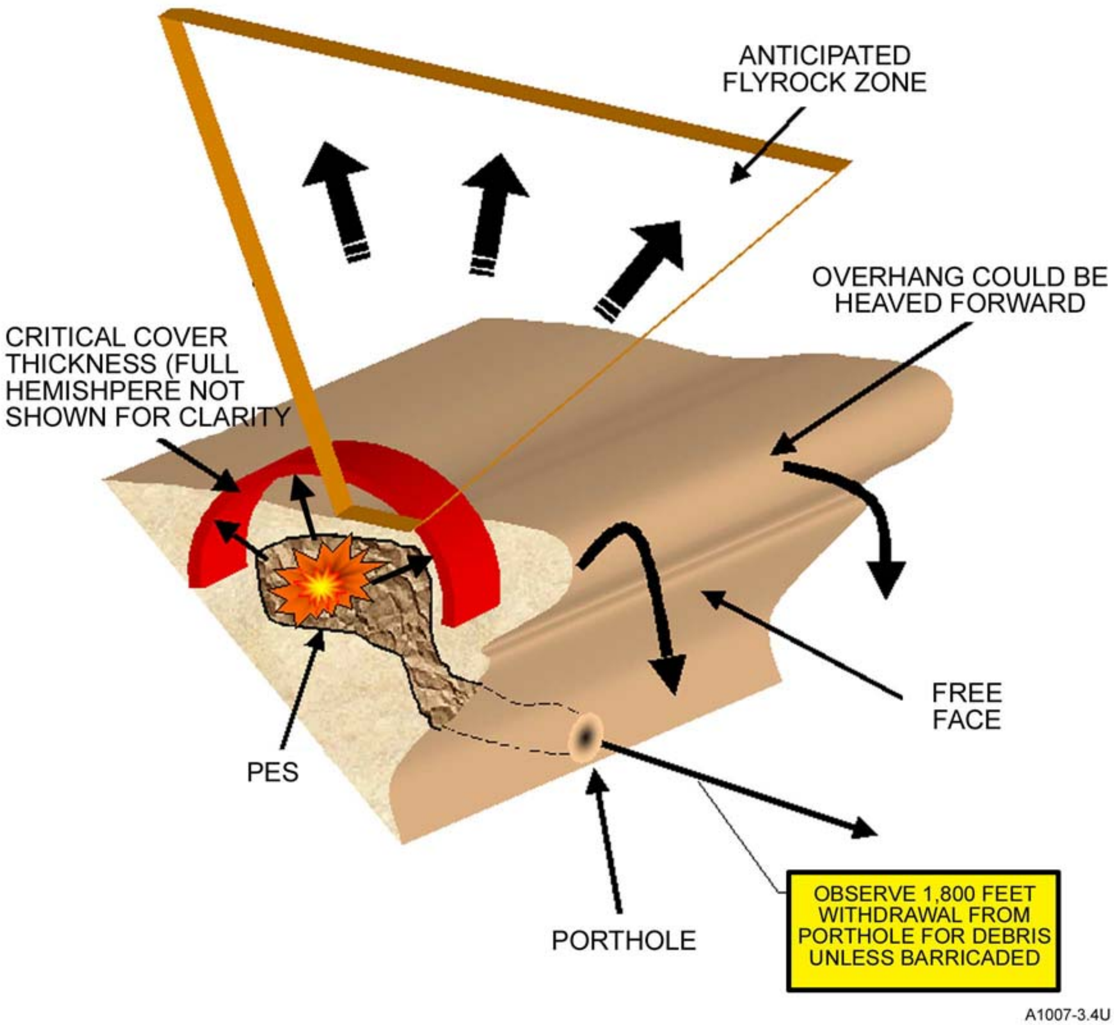


Figure 3-4. Deep Cave or Tunnel

Figure 3-4

DEEP CAVERN OR TUNNEL

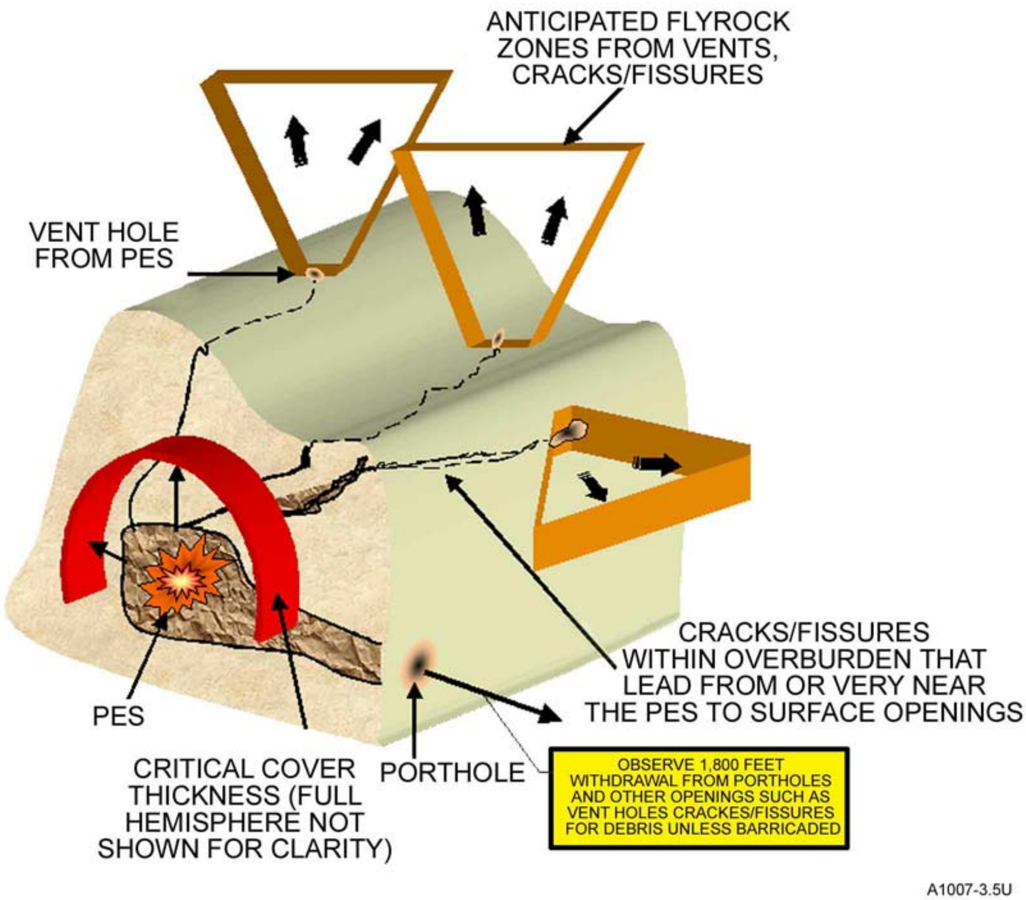


Figure 3-5. Deep Cave or Tunnel with Cracks or Fissures Leading from PES

Figure 3-5
DEEP CAVE OR TUNNEL WITH CRACKS OR FISSURES LEADING FROM PES

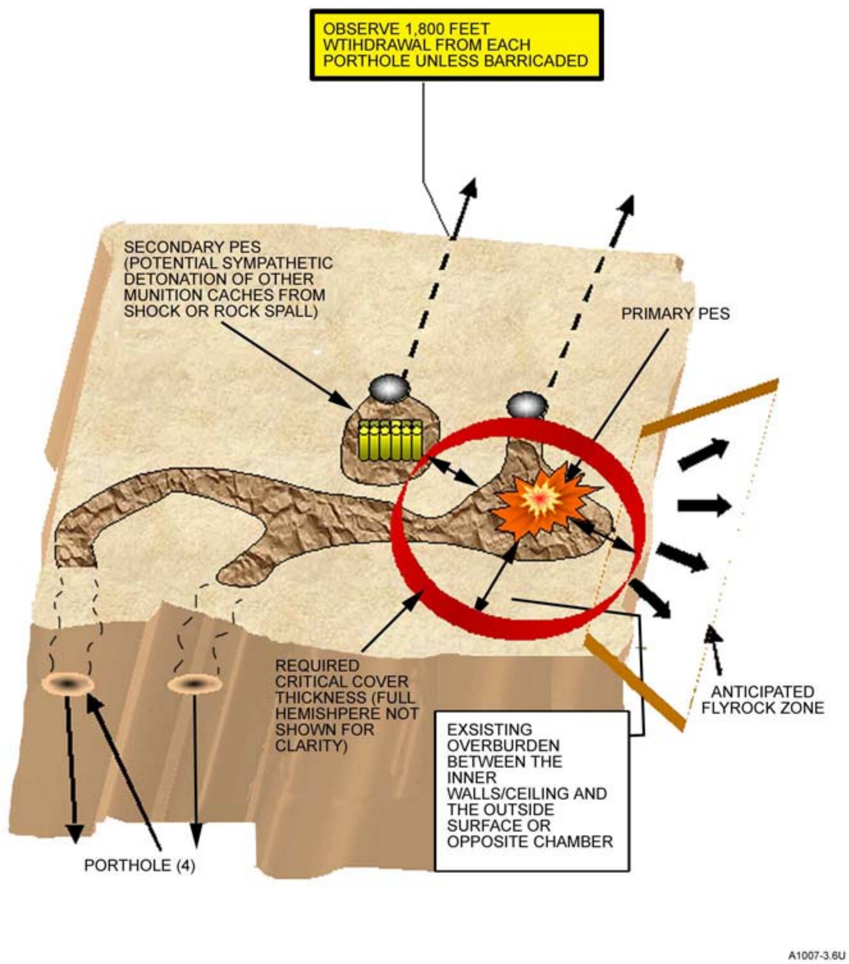


Figure 3-6. Cave or Tunnel with Multiple Exposures

Figure 3-6
CAVE OR TUNNEL WITH MULTIPLE EXPOSURES

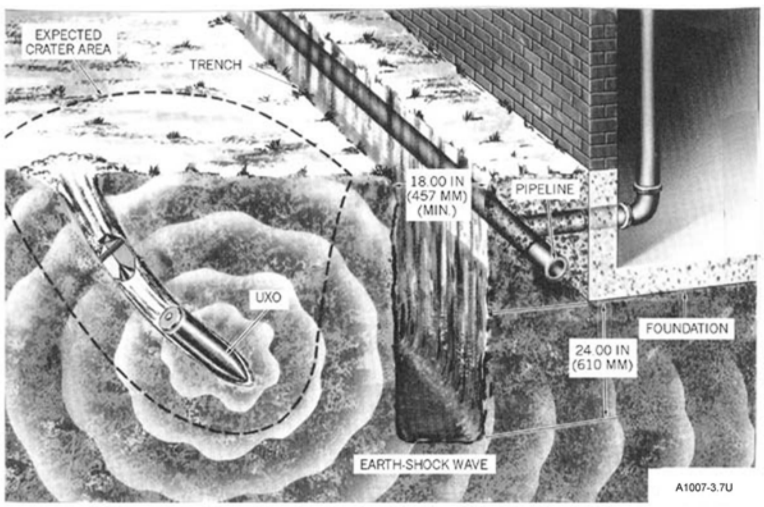


Figure 3-7. Trenching to Protect Against Earth-Shock Wave.

Figure 3-7

TRENCHING TO PROTECT AGAINST EARTH SHOCK WAVE

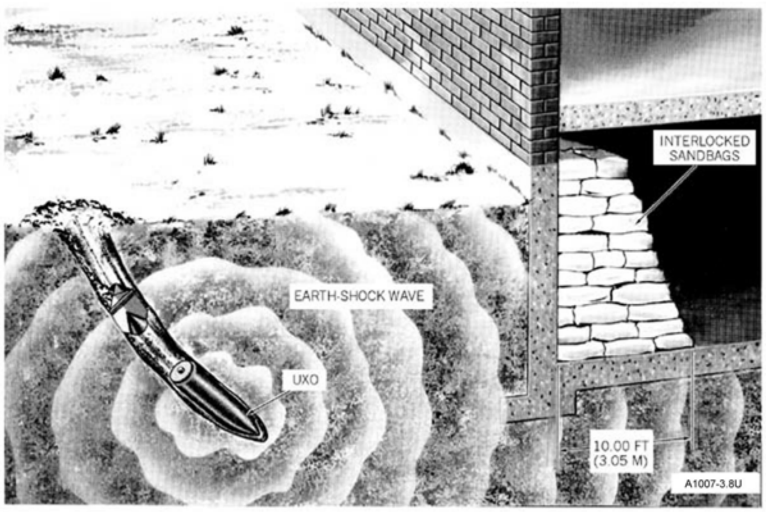


Figure 3-8. Application of Sandbag Buttress for Protection Against Ground Shock Wave

Figure 3-8
APPLICATION OF SANDBAG BUTTRESS FOR PROTECTION AGAINST GROUND SHOCK WAVE

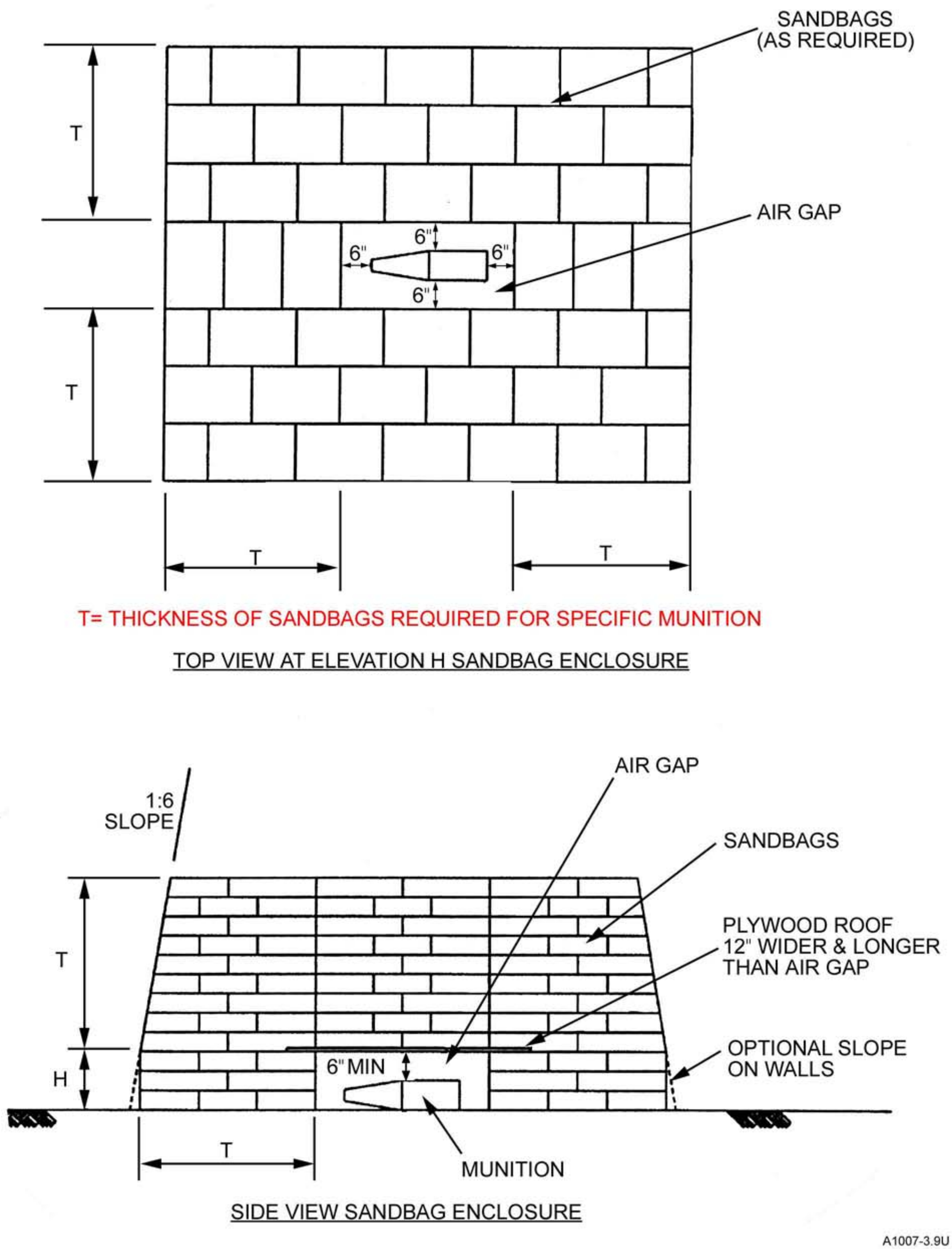


Figure 3-9. Sandbag Explosion Effects Mitigation Technique

Figure 3-9
SANDBAGS EXPLOSION EFFECTS MITIGATION TECHNIQUE